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Contamination Assessment for OSSA Space Station IOC Payloads

S. Chinn, T. Gordon,
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Contamination Assessment for OSSA Space Station IOC Payloads

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1.0 INTRODUCTION

This final report summarizes the results of the "Contamination Assessment for OSSA space station IOC Payloads", purchase order #H 132929 and P.O. 135068. The duration of the study was from 6 May 86 through 24 November 86.

The funding originated from the Office of space science and Applications, CODE E. Figure 1.1 shows the organization flow for this study.

1.1 OBJECTIVES

There were two main initial objectives.

- o Provide realistic contamination requirements for space station attached payloads, serviced payloads and platforms.
- o Determine unknowns or major impacts requiring further assessment.

1.2 SCOPE

The initial scope of the study was ambitious and is graphically shown in Figure 1.2. The major emphasis was decided to be the attached payloads and a cursory look at free fliers, platforms and the interior payloads.

1.3 APPROACH

The initial approach was to:

- o Review data sources
  - OSSA Planners
  - Principal Investigators
  - MSFC
  - GSFC
  - LARC

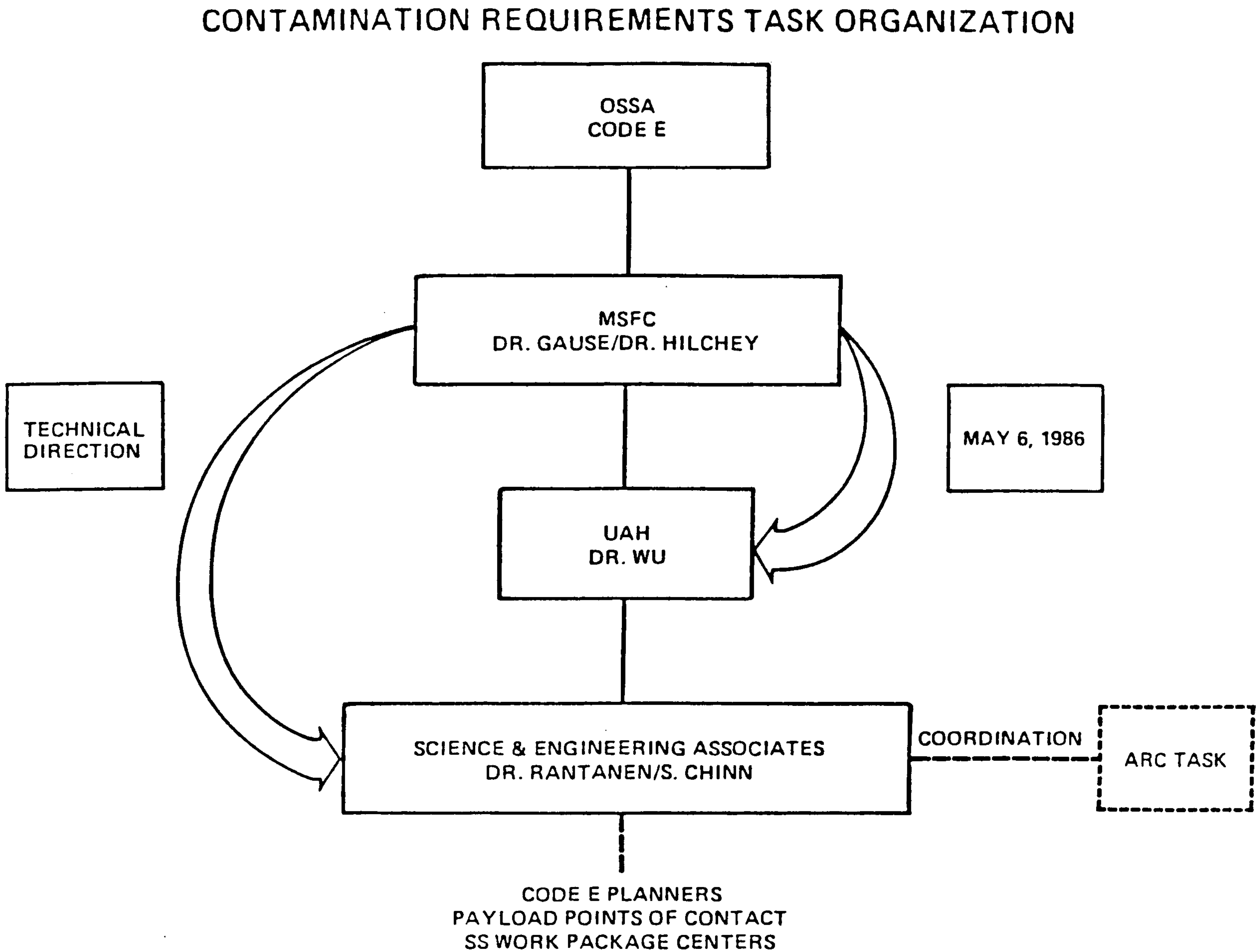

FIGURE 1.1. CONTAMINATION REQUIREMENTS TASK ORGANIZATION

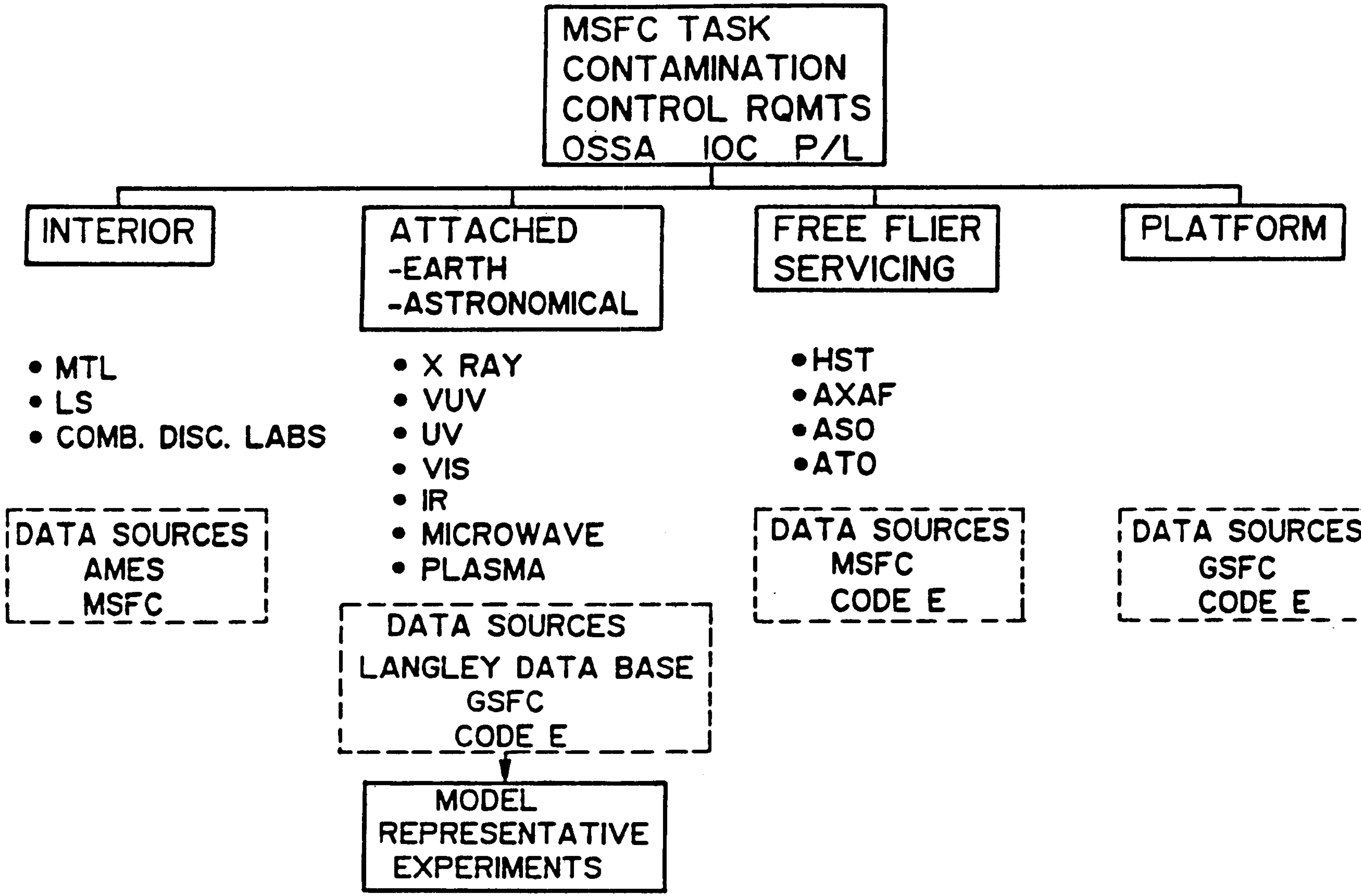

FIGURE 1.2. STUDY SCOPE

- AMES

- Utilize request for information forms
- Visit P.I.'S
- Assess contamination sources
- Compile results

Figure 1.3 illustrates the flow in the data acquisition process.

1.4 SUMMARY

The initial objectives of this study were successfully completed.

The contamination requirements in JSC 30000 section 3 were updated and presented at a working meeting, 13-14 Aug. '86, of the Contamination Control Working Group headed by Dr. Lubert Leger. At this meeting an agreed upon set of requirements was arrived at by all attendees. This included, GSFC, MSFC, JSC, LeRC, OSSA CODE E, JPL, NRC CANADA, NASDA JAPAN, ESA, Science and Engineering Associates, Martin Marietta and McDonnell Douglas. Major improvements from a user viewpoint were achieved at the meeting.

Action items occurred during the course of the study which aided in expanding and detailing the second objective. These action items included venting and leakage issues, ambient atmosphere effects and the impact of transverse boom versus dual keel.

These actions were summarized and presented at a series of meetings. Those of note were:

- NASA Headquarters, 11 August 1986, on requirements and venting issues in preparation of the CCWG meeting at JSC.
- NASA Headquarters, 17 September 1986, on transverse boom versus dual keel impact on contamination.

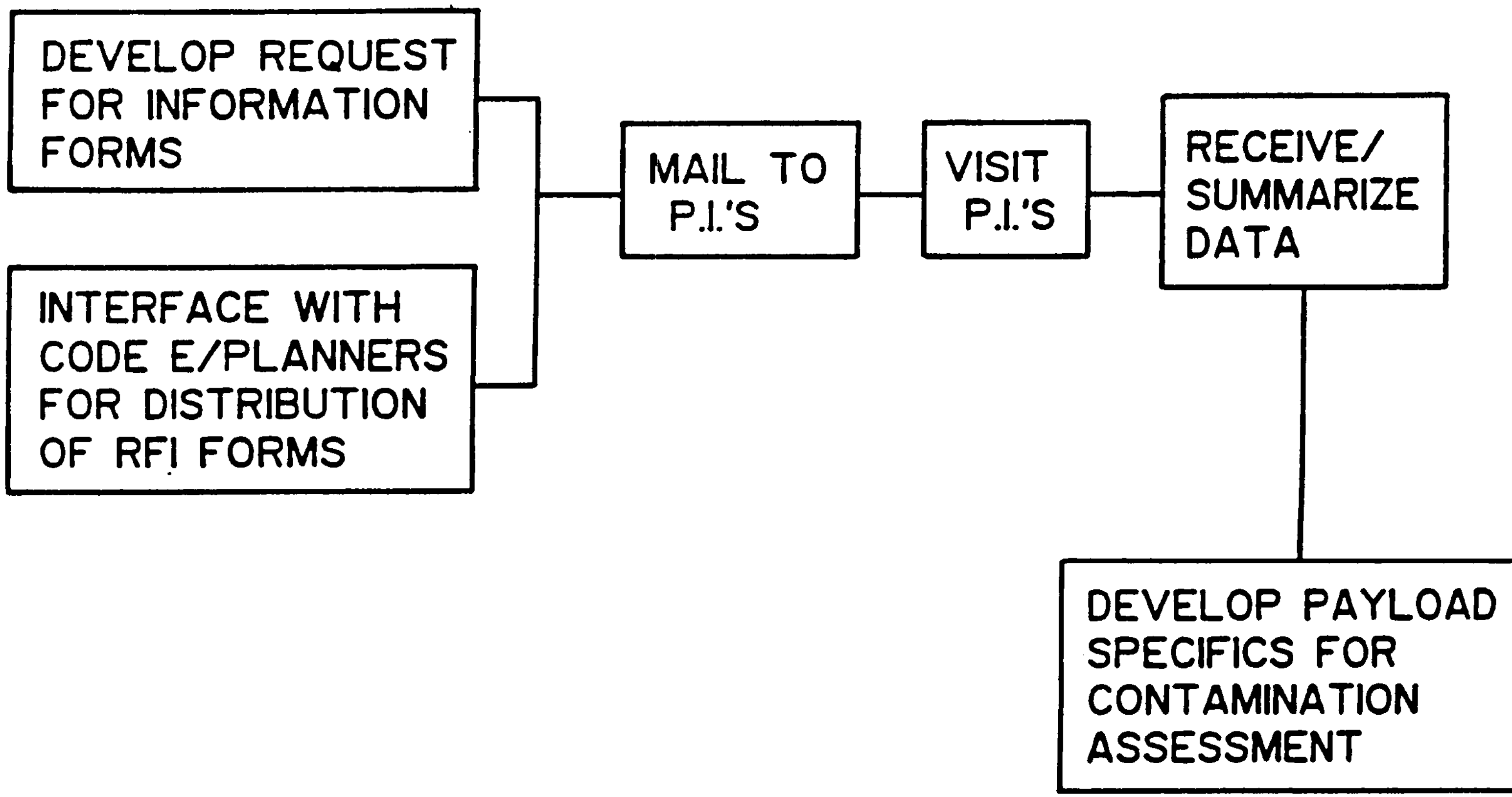

FIGURE 1.3. DATA ACQUISITION SCENARIO

Attendees from NASA/MATSCO were:

Richard Sade

John Hilchey

Arnold Nicogossian

Mike Davarian

Gary Musgrave

Larry Chambers

o NASA Headquarters, 22 September 1986, on transverse boom versus dual keel impact on contamination.

Attendees from NASA/MATSCO were:

Dick Halpern

Mike Davarian

Sam Keller

Gary Musgrave

David Black

Fritz Von Bun

Ray Gause

Lubert Leger

Horst Ehlers

Ed Reeves

Mark Sistilli

Larry Chambers

The approach to mail out request for information forms met with partial success. The response was limited. It became clear that acceptable levels of contaminants is not well known or understood by the payload community.

As a result of this study future plans are underway to accurately determine background brightness levels, absorption losses, surface reflectance and transmission changes. By comparing these to a space station environment and payload allowable levels the impact of contamination can be assessed.

2.0 CONTAMINATION DESCRIPTION - EXTERNAL

This section presents the general types of contamination that can occur to familiarize the reader with the concepts discussed in the following sections. The contamination discussed here relates to external contamination that a payload experiences external to a spacecraft. Section 2.8 presents data and algorithms to aid in estimating the different levels of contaminants.

Figure 2.1 shows the key elements in performing a contamination analysis. For a given geometry there are 3 major elements required. These are source kinetics, transport mechanisms and degradation effects.

2.1 DEFINITIONS

The following definitions summarize the key concepts. Some of the more pertinent are discussed in more detail in the remaining portion of this section.

- CONTAMINATION - Spacecraft or payload induced molecular or particulate environment that degrades or interferes with a measurement or degrades an operational or critical sensor surface that requires refurbishment before continued use.
- LINE-OF-SIGHT - The viewing direction of a sensor or instrument relative to the space station or platform.
- FIELD-OF-VIEW - The solid angle of the line-of-sight of a sensor or instrument.

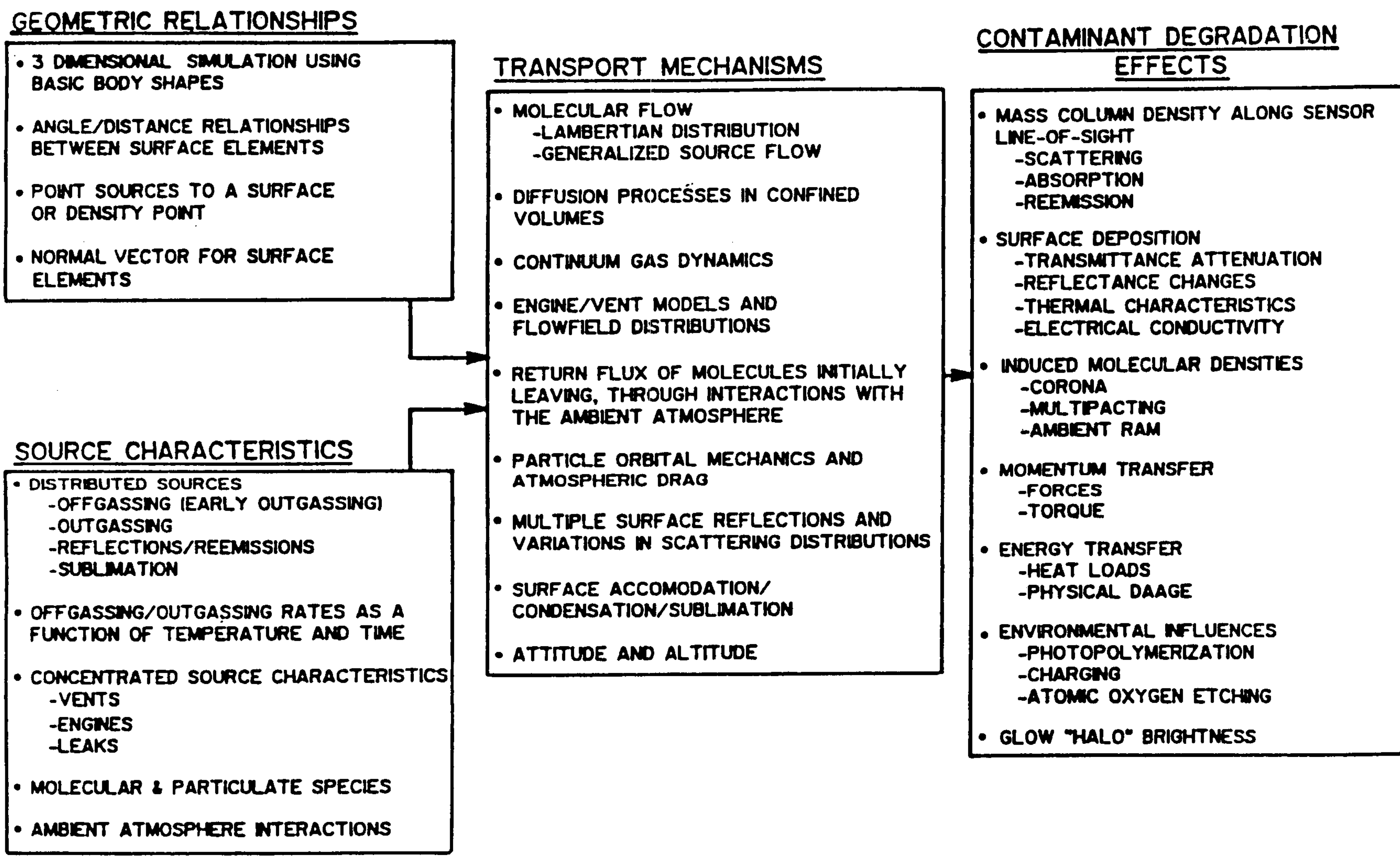

FIGURE 2.1. KEY ELEMENTS FOR CONTAMINATION ASSESSMENT AND MODELING

o <u>OPERATIONAL SURFACE</u> - Those surfaces that are not part of a sensor optical train that are required for nominal space station operations, including thermal control surfaces, solar array surfaces, and windows.

o <u>CRITICAL SURFACE</u> - Those surfaces that are required for successful operation of a sensor or instrument including optics, baffles, and sun shades.

o <u>COLUMN DENSITIES</u> - The amount of mass or number of molecules per unit area along the field-of-view of a sensor, which can scatter, absorb, or reemit at the sensor operating wavelength.

o <u>RETURN FLUX</u> - The return of emitted contaminant molecules back to spacecraft surfaces via collision interactions with the ambient atmosphere.

o <u>DEPOSITION</u> - The accumulation of molecular or particulate contaminants on a surface that changes the surface characteristics (transmittance, reflectance, conductivity, absorptivity, emissivity).

o <u>RAM DENSITY</u> - The pressure buildup of ambient and induced contaminant atmosphere on spacecraft surfaces facing the direction of motion as a result of orbital velocities exceeding ambient molecule thermal velocities.

o <u>SURFACE GLOW</u> - The Broad spectral emissions from gases interacting at or near ram facing surfaces.

o <u>FAR FIELD GLOW 'HALO'</u> - The broad spectral emissions from gases upstream from ram facing surfaces and in the wake region of the spacecraft.

o <u>OUTGASSING</u> - Molecular emissions that diffuse from the bulk of a material.

o OFFGASSING - Molecular emissions of a highly volatile species that adsorb or absorb on or into the surface of a material prior to vacuum exposure.

2.2 NUMBER COLUMN DENSITY

The molecular species induced by the spacecraft, the payload itself or ambient atmosphere interactions that reach the field-of-view of an experiment, can cause degradation of the signal. The degradation effect is a function of the payload sensing wavelength, target strength, optical properties of the contaminant gas, orbital position and spatial/temporal uniformity requirements for the data acquisition techniques involved.

The gases can either absorb, scatter or reemit at the sensor operating wavelength. Ions of these gases are also possible via ambient interaction or gas phase charge exchange mechanisms.

These gases do not build up a static cloud. Instead the cloud is constantly added to by the sources, and dissipates very rapidly. Therefore only those sources continuous in nature will always be present. The types of sources that are continuous are leakage, ram pressure and outgassing. Sources such as vents, airlock operations and RCS thrusters will be transient in nature and will cause varying background levels.

2.3 DIRECT FLUX/DEPOSITION

Surfaces that see other surfaces can outgas directly onto these surfaces. Depending on the source and the relative temperature of source and receiver, a fraction of the outgassed flux can deposit and degrade the properties of the receiving surface.

2.3.1 Ultra Violet Effects

The presence of ultraviolet radiation can cause two major differences in the deposition assessment.

First it can photopolymerize the deposit on a surface so that it changes the character of the deposit. Usually the deposit changes toward a darker color and becomes much more tenacious .

Secondly, the presence of UV during flux of contaminants can cause the deposition rate to increase or cause deposition to occur when it normally would not. Testing has shown that with UV present deposition can occur even though the receiver is at a higher temperature than the source.

2.4 RETURN FLUX/DEPOSITION

The return flux mechanism occurs via interactions of the contaminant with the incoming ambient atmosphere. Since the incoming ambient is a unidirectional, well collimated beam the amount of return flux is strongly dependent on the velocity vector relative to the receiving surface in question. Figure 2.2 schematically illustrates the condition for return flux. The field-of-view (solid angle of optical system sensing volume) also dictates the fraction of contaminants that can backscatter onto sensitive surfaces.

The amount that can deposit is a function of the parent source material type and temperature, and the receiver temperature. UV can play the same role as mentioned in section 2.3.1 above.

2.5 RAM PRESSURE

For spacecraft in low earth orbits there is genuine reason for concern with regards to the contamination effects resulting from the ambient atmosphere. The ambient atmosphere is composed primarily of H, O, O_2, N_2, and He, at low orbital altitudes. As the spacecraft passes through the ambient atmosphere at orbital velocities, ambient molecules collide with RAM facing surfaces. Many of these molecules are thermally accommodated on the spacecraft surfaces and reemitted with thermal

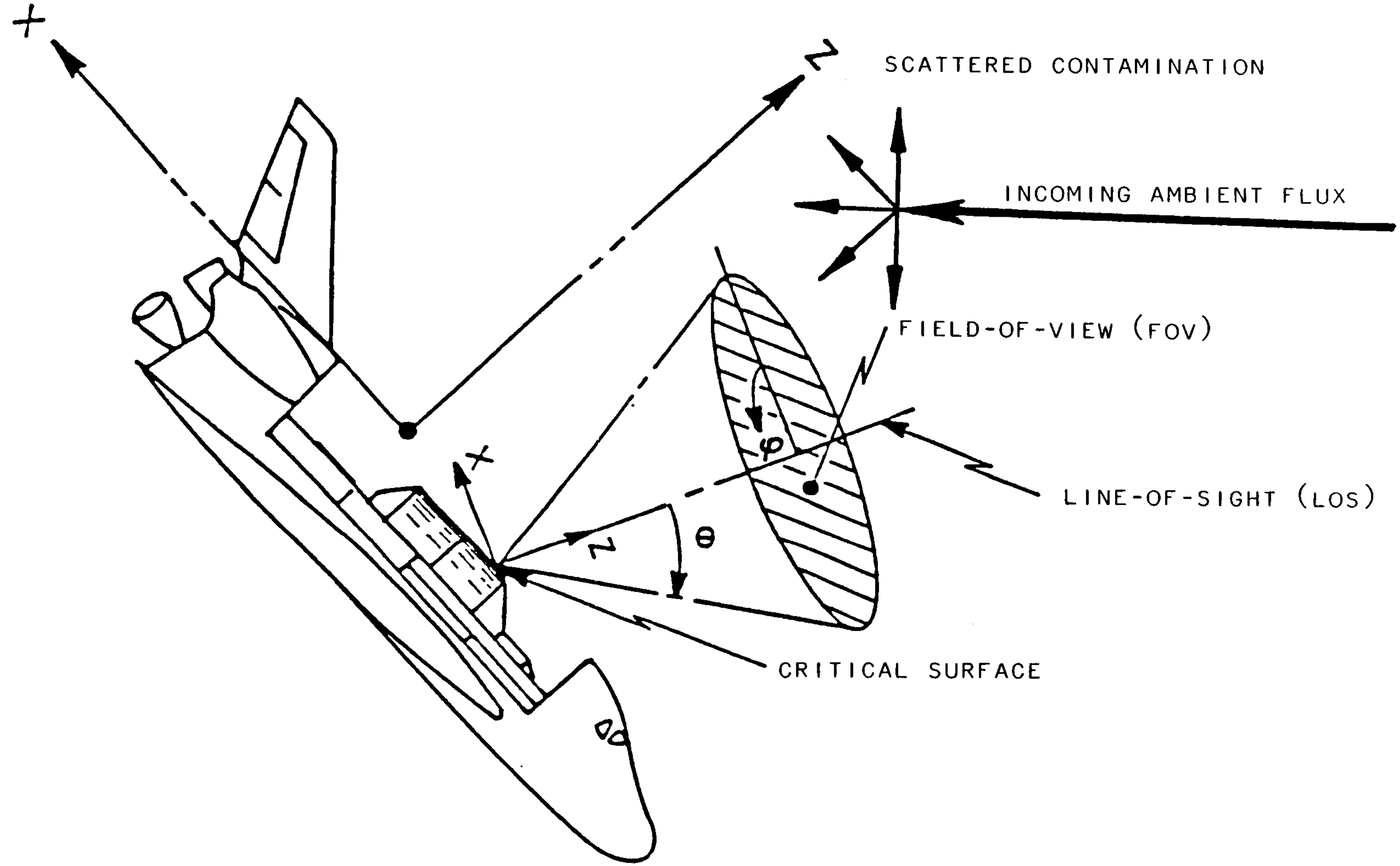

FIGURE 2.2. RETURN FLUX

velocities as ambient species as well as ambient combination species. The reemitted molecular species might include H, O, O_2, N_2, NO_2, NO and OH. In addition to the reemitted ambient and ambient combinations, depending on the surface material, outgassed and erosion products may also leave the spacecraft surfaces.

Regardless of the source, molecules leaving the surface will tend to be scattered along the RAM direction vector by the free-streaming ambient and ambient scattered molecules. In the case of a surface oriented perpendicular to the RAM direction vector, the scattering distribution will be directed back towards the emitting surface. The backscattered molecules further decrease the expected mean-free path of the surface emitted molecules. The result is a density buildup near the RAM facing surfaces. The higher density region near RAM facing surfaces produces a contamination environment considerably different from what would be expected if only an undisturbed ambient atmosphere were considered. Many of the surface reemitted molecules may be ambient combinations such as NO_2, and OH which are of more concern to UV and IR instruments than the ambient molecular constituents in an uncombined form. Further more, slow moving outgassed and erosion products may become somewhat trapped in the higher density regions resulting in higher than expected contaminant level for some molecules. The complete ramifications of the density buildup (RAM pressure) are not fully understood at this time, but should be considered when determining the contamination environment.

2.6 GLOW

The glow of the space shuttle was first detected during the flight of STS-3. Although the shuttle glow was not specifically predicted it has now been associated with other spacecraft glow which was shown to surround free flyer satellites such as Atmosphere and Dynamics Explorer [Torr et al., 1977; Torr, 1983; Yee and Abreu, 1983]. Specific investigation into the shuttle glow began on STS-4 when a transmission grating was mounted in front of a photographic camera and several exposures were taken on-orbit to make preliminary spectral measurements of the spacecraft glow [Mende et al., 1983]. Investigation into the glow phenomenon continued on STS-5,8,9, 41D and finally 41G.

The data gathered from the various flight experiments suggest the glow is a continuum (within 34Å FWHM resolution) and extends 20cm out from the surface. The continuum shape (Fig. 2.6.1) is such that the peak is near 7000Å decreasing to the blue and red. In addition to the spectral

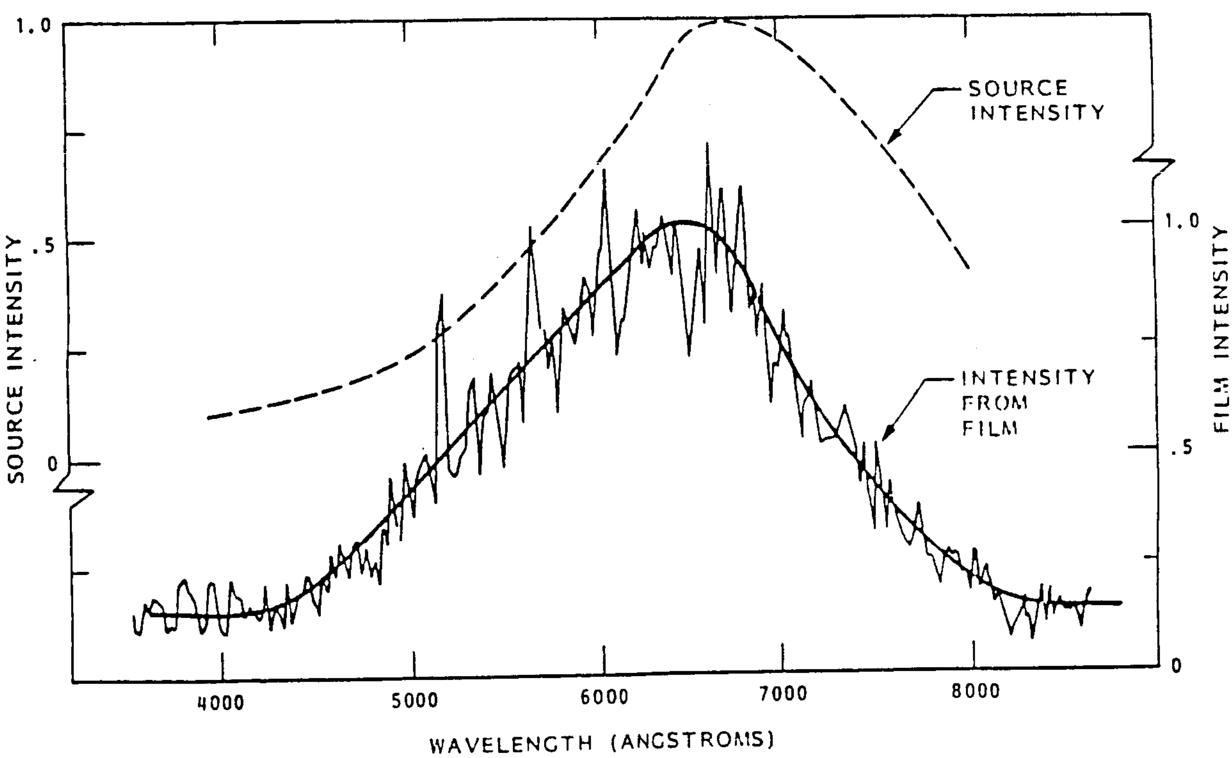

FIGURE 2.6.1 GLOW SPECTRUM

data, other parameters were also investigated in an attempt to better characterize the glow phenomenon.

Examination of the photographs from STS-3 showed that only those surfaces which were in the direction of the velocity vector exhibited glow. In an experiment on STS-5, it was verified that the glow intensity strongly depends on the attitude of the surface with respect to the velocity vector. In this experiment a full 360 roll was executed about the shuttle x-axis while the orbital velocity vector was in the shuttle x-y plane. During the experiment, photographs were taken of the tail section at 2-minute intervals to record the intensity of the glow on the tail surfaces (Fig 2.6.2).

Measurements by Yee and Abreu [1983] from atmosphere explorer data found that in the altitude regime of the shuttle, the intensity of the spacecraft glow varied in the same manner as the atomic oxygen density.

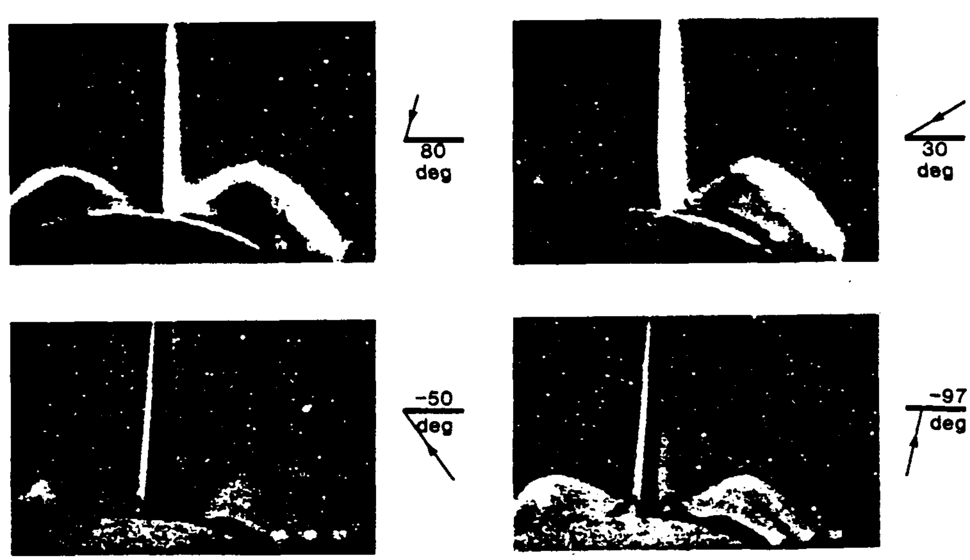

FIGURE 2.6.2 GLOW vs ATTITUDE

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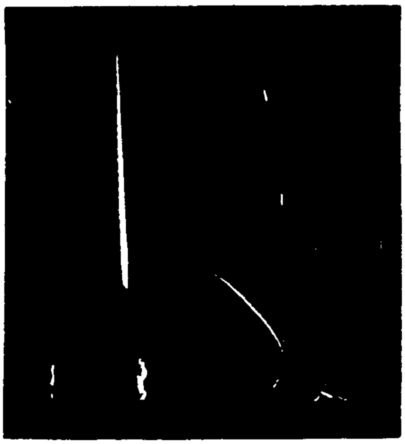
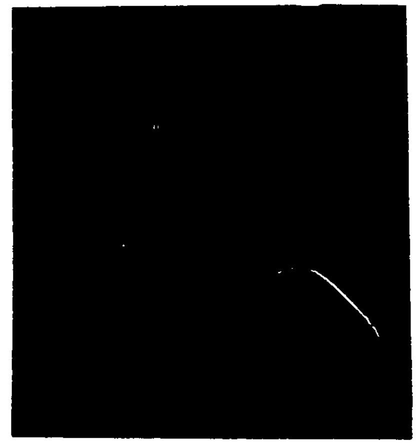
Since the shuttle flights are essentially in circular orbits, measurements have been restricted to comparisons between one flight to the next. A good comparison is provided in Figure 2.6.3 A & B where STS-3 (A) and STS-5 (B) images are shown.



(A)



(B)

FIGURE 2.6.3 GLOW VS. ALTITUDE

The image of STS-3 was taken at an altitude of 240 km and STS-5 at 305 km. Both images were taken with the same camera and lens. From the photographs one can see the glow is nearly the same. The difference in the two images was the exposure time, STS-3 was 10 seconds and STS-5 was 100 seconds. Corrections were made for the difference in exposure times and film reciprocity failure. These corrections allowed a ratio of 3.5 for the real intensities to be determined. The intensity data from these two photos shows a fairly good agreement with the scale height variation of atmospheric constituents.

The dependence of the glow intensity on the nature of the spacecraft surface was investigated on STS-5 and 41D. For the experiment on STS-5, ten 4-inch wide material tapes were mounted on the remote manipulator system (RMS) arm. The materials used for this experiment were Kapton, aluminum, black chemglaze, aluminum and Kapton. A second set of samples were repeated in this order. Photographic images of the material samples on the RMS arm were taken. Analysis of these images reveal the glow from the chemglaze was strongest with aluminum glowing the least. The experiment just described was repeated on STS-41D using nine different material samples. The materials chosen for this experiment were MgF_2, Z306, Z302 overcoated with Si, Z302, polyethylene, 401-C10, carbon cloth, a chemical conversion film and anodized aluminum. Again these material samples were photographed with the same instrument as in STS-5. Analysis of the images reveal the glow from the Z302 overcoated with Si was brightest and the polyethylene glowing the least. Table 2.6.1 shows the rest of the materials and their ranking (1 to 9 in order of glow intensity, minimum to maximum, respectively).

Table 2.6.1 RMS Arm Materials Ranking

Material	Ranking
MgF_2	8
Z306	6
Z302 Overcoated with Si	9
Z302	7
Polyethylene	1
401-C10	2
Carbon Cloth	4
Chemical Conversion Film	5
Anodized Al	3

The success of these experiments was that it provided solid evidence that the observed glow is somehow dependent on the properties of the material surface.

To this point, the discussion has concentrated mainly on surface glow observations. There is, however, another aspect of the glow that has been overlooked by most glow investigators, that being the far-field glow. During the STS-9 mission, Fred C. Witteborn and colleagues from the Ames Research Center conducted observations of the shuttle using the Advanced Research Projects Agency's Maui Optical Station (AMOS) tracking facility. The observations were made using a sensitive photometer in two infrared bands, the H-band centered at a wavelength of 1.6μ and the K-band centered at 2.3μ. The results of the tracking of STS-9 are summarized in Table 2.6.2.

Table 2.6.2 Shuttle Glow in the IR

Wavelength μ	Best measured flux density $W\ cm^{-2}\mu^{-1}$	Flux density minus scattered radiation $W\ cm^{-2}\mu^{-1}$	Estimated irradiance of Shuttle glow $Wcm^{-2}\mu^{-1}\ sr^{-1}$	Zodiacal irradiance $Wcm^{-2}\ \mu^{-1}sr^{-1}$
1.6	2.2×10^{-16}	2.2×10^{-16}	6.0×10^{-8}	2.4×10^{-12}
2.3	1.09×10^{-16}	Negligible	Negligible	7.0×10^{-12}

The emitted flux from STS-9 at 1.6μ is much higher than can be accounted for by the shuttle's thermal radiation or by scattered radiation from the earth or its atmosphere. It is concluded by Witteborn that this excess IR environment around the shuttle would be 200 times brighter than the zodiacal background at an altitude of 400 km. The spatial extent of the IR glow at 1.6μ. shows it to be tens of meters away from the shuttle.

2.7 ATOMIC OXYGEN EROSION

From the earliest Shuttle flights it became apparent that many materials exposed to the environment had undergone various changes. The most dramatic effects were seen in Kapton which showed severe mass loss and loss of surface gloss. Also, painted surfaces showed apparent aging effects. To explain these observations, it has been hypothesized that atomic oxygen which is the predominate species in low earth orbit (LEO), is somehow reacting with the materials to cause these results. The important factor in the reaction process comes from the collisional energy (5eV) of the atomic oxygen which is derived from the orbital velocity of the vehicle (8km/sec.).

The results from the first Shuttle flight prompted the need for further investigation into this phenomenon. Material samples were flown on STS-3, 4 and 5 in an attempt to further evaluate the effects of atomic oxygen on materials. Table 2.7.1 summarizes the results of these experiments. The reaction efficiency (R.E.) shown in Table 2.7.1 is derived by normalizing the thickness loss induced by the calculated atomic oxygen fluence to yield R.E.= xcm^3/oxygen atom.

Table 2.7.1 STS-3, 4 and 5 Material Sample Results.

Shuttle Flight	Material	Thickness, μm (a)	Thickness Loss, μm	Fluence 10^{20} Atoms/cm^2	Reaction Efficiency 10^{-24} cm^3/Atom (b)
STS-3	Kapton TV Blanket	12.7	4.4	2.16	2.0
	Kapton, OSS-1 Blanket	25.4	5.5		2.5
STS-4 Witness Samples	Kapton MLI Blanket				
	Kapton	7.6	1.8	0.65	2.8
	Kapton	12.7	1.6		2.7
	Kapton	25.4	1.7		2.6
	Mylar	12.7	1.8		2.8
	Teflon FEP 7 TFE	12.7	0.07		0.1
	Al/Teflon FEP				
STS-5 Witness Samples	Kapton	12.7	1.50	1.0	1.5
	Kapton	25.4	2.18		2.2
	Kapton	50.8	2.79		2.8
	Kapton, Black	25.4	1.35		1.4
	Mylar	12.7	2.16		2.2
	Mylar	25.1	1.83		1.8
	Mylar	50.8	1.50		1.5
	Tedlar, Clear	12.7	1.30		1.3
	Tedlar, White	25.4	0.41		0.4
	Teflon FEP & TFE	12.7	0.2		0.2
	Kapton (Coated)				
	DC1-2755	12.7 (Kapton)	0.2		0.2
	T-650	12.7 (Kapton)	0.2		0.2

(a) Note: Film Thicknesses of 12.7, 25.4, and 50.8 μm correspond to 0.5, 1.0 and 2.0 mils, respectively.
(b) Most probable error is +30 to 40%.

Additional material samples were flown on STS-8 and the results are shown in Table 2.7.2.

Table 2.7.2 STS-8 Material Sample Results.

Material	Thickness, µm (MILS)	Exposed Side[a]	Surface Recession,[b] µm				Reaction Efficiency 10^{-24} cm^3/atom
			Strip Samples		Disc Samples	Average[c]	
			121°C	65°C			
Kapton	12.7 (0.5)	Air	9.5	10.5	11.1		
		Roll	11.8	10.3			
Kapton	25.4 (1.0)	Air	9.8	10.7			
		Roll	9.9	9.0		10.5	3.0
Kapton	50.8 (2.0)	Air	11.1	10.6			
		Roll	11.1	11.1			
Mylar A	12.7 (0.5)	Air	12.7	12.3	12.7	12.6	3.6
Mylar A	40.6 (1.6)	Air	12.1	11.9		12.0	3.4
Mylar D	50.8 (2.0)	Air	9.9	10.2		10.4	3.0
		Roll	11.0	10.4			
Clear Tedlar	12.7 (0.5)	Air	10.9	11.5		11.2	3.2
Polyethylene	20.3 (0.8)	N/A			11.5	11.5	3.3
Teflon TFE	12.7 (0.5)	Air			<0.2	<0.2	<0.05
Kapton F	30.5 (1.2)	N/A	<0.2	<0.2	<0.2	<0.2	<0.05

The observed "aging" of paints detected on STS-1 through STS-4 were extended on later flights with measurements of quantitative optical changes. The changes in emissivity (ε) and absorptance (α) were measured post-flight and are shown in Table 2.7.3.

Table 2.7.3 STS 1-4 Material Sample Results

Paint	Δε	Δα	Other Comments	Refs
A-276 Urethane, White	+0.03	−0.0007		G-5
A-276 + 5% Ir (Ir = Irganox)	+0.02	+0.0007		
A-276 + 5% Ir + 2.5% Ti292 (Ti = Tinuvin)	+0.02	+0.016		
A-2767 + 5% Ir + 2.5% Ti900	+0.02	−0.006		
V-200 Urethane	+0.02	+0.02		
V-200 + 5% Ir + 2.5% Ti292 + 2.55% Ti900	+0.02	+0.097		
V-200 + 2.5% Ir + 5% Ti292	+0.02	+0.057		
RTV-615 Silicone + TiO_2	-0.01	+0.0001		
RTV-615 + Carbon Black	0	0	Resistance Increase x2 per Unit Area	
Urethane + Carbon Black	+0.05	+0.0053	Resistance Increase x3 per Unit Area	
Flame Master S1023	-0.02	-0.02	11.3% Wt Loss; Oxygen Increase 25-50%	G-6
Chemglaze Z306	-0.02	+0.034	4.8% Wt Loss; Oxygen Increase 400-500%	
401-C10 (Black)		+0.005	Wgt Loss mg/0 Atom 0.86 x 10^{-21}	G-7
Z-853 (Yellow)		-0.034	0.9 x 10^{-21}	
GSFC (Green)		-0.002	No Change	
Z306 (Black)		+0.028	1 x 10^{-21}	
Z302 (Glossy Black)		+0.043	5.8 x 10^{-21}	
Z302 + OI 650 Overcoat		-0.001	No Change	
Z302 + RTV 670 Overcoat		-0.004	No Change	
A276		-0.002	1 x 10^{-21}	
A276 + OI 650 Overcoat		+0.002	0.1 x 10^{-21}	
Electrodag 402 (Ag/Silicone)			2% Wt Loss	G-3
Electrodag 106 (Gr/Epoxy)			68% Wt Loss	
Aquadag E (Gr/Binder)			100% Wt Loss	

A variety of materials have been flown on the Shuttle and the effect of the oxidation/erosion environment on various properties were investigated. The observations from the various flight experiments can be summarized as follows:

1.) Materials containing carbon, hydrogen, oxygen and nitrogen have high reaction rates which have the range of 2.5×10^{-24} to 3.0×10^{-24} cm^3/atom.

2.) Perfluorinated and silicone polymers are more stable than organics by at least a factor of 50.

3.) The reaction rates for filled organic materials are dependent on the oxidative stability of the fillers. For example, materials filled with metal oxides have lower reaction rates than those filled with carbon.

4.) From a macroscopic standpoint, metals, except for osmium and silver are stable. Metals such as copper do form oxide layers, but at much lower rates.

The results of the various materials oxidation/erosion experiments are extremely important to the compatibility and survivability issues associated with the long life of the space station Program. This unique long life requirement makes selecting materials and hardware difficult. The proper selection of materials will set a precedent for future long life space programs.

2.8 PAYLOAD SENSITIVITY TO CONTAMINATION

Molecular and particulate species can degrade an optical system by depositing on optical surfaces or residing in the field-of-view of the instrument. Additionally, on orbit contamination in the form of orbital debris can degrade thermal control surfaces or create other damage.

2.8.1 Contaminants in the Field-of-View

The number column density of molecular or particulate species can either absorb, scatter or reemit radiation at the sensing wavelength of an instrument.

Figure 2.8.1 shows an estimate of absorption of molecular species within an experiment line-of-sight for wavelengths between 500 and 1700Å. The upper limits on column densities were based on 50Å intervals, such that a maximum absorption of 0.1% through the species under consideration would occur at any 0.01Å wavelength band within each 50Å interval.
This same type of data can be developed for visible and infrared systems.

Even though the levels shown in Fig. 2.8.1 are stated as acceptable for absorption they may not be for scattering or emissions.

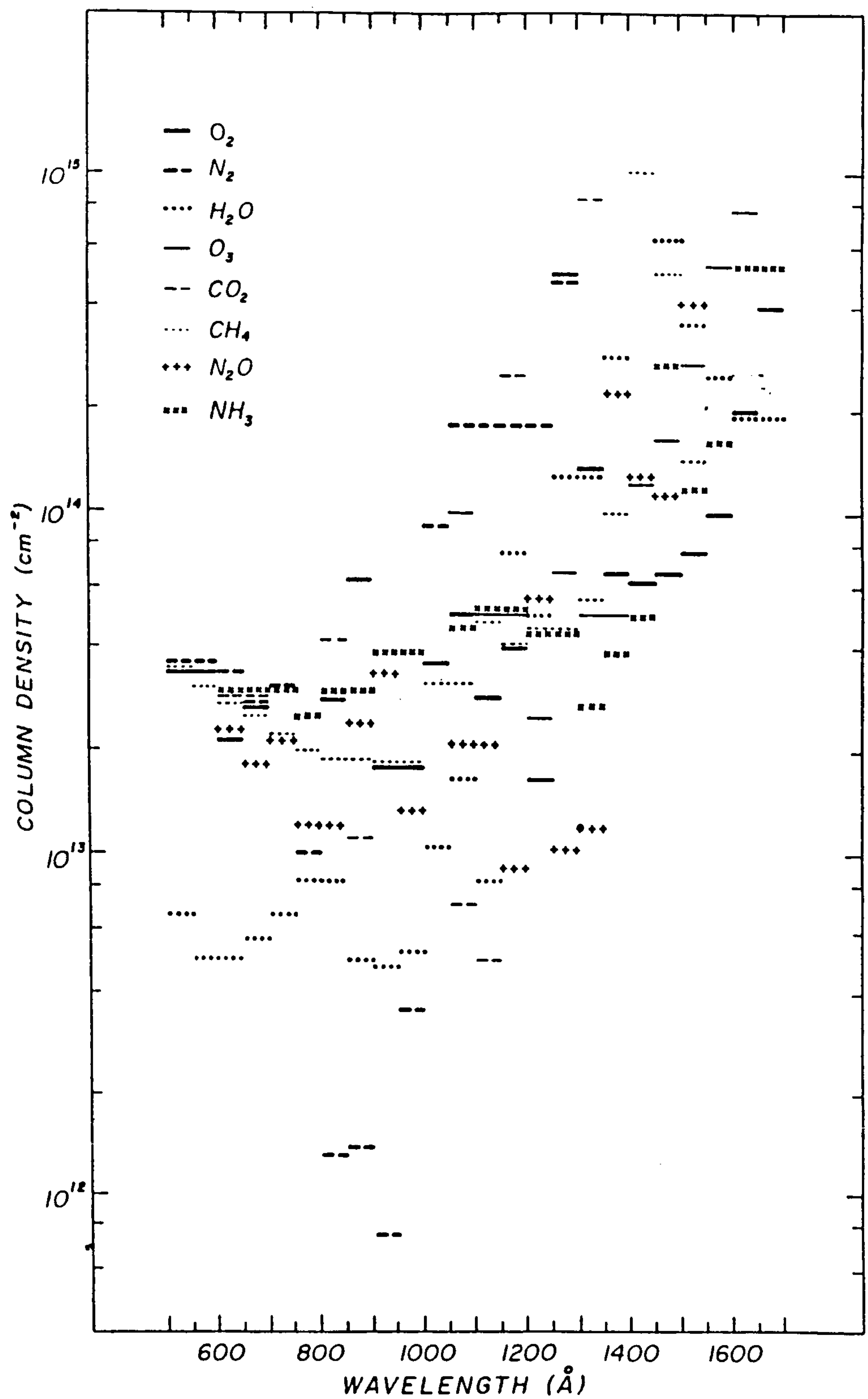


FIGURE 2.8.1 MAXIMUM ALLOWABLE COLUMN DENSITIES OF GASEOUS SPECIES

Scattering for a given species is a function of viewing direction and position on orbit. The target brightness will determine how much increase in the background is allowable due to scattering.

The emissions of the gases in a field-of-view depends on the species and the excitation cross section for different mechanisms. Photons, electrons, collisions and thermal state of the source are types of excitation mechanisms. The intensity of the excitation mechanisms will vary within an orbit, will change from orbit to orbit and can be influenced by spacecraft attitude and contaminant source rate.

Ionized species will produce different spectra and must be determined/calculated based on potential ionization excitation cross sections, and photochemistry effects.

The density of the contaminant gases can influence excited states by quenching or charge exchange.

Overall, emissions of the contaminant gases is the most difficult to predict over all wavelengths. Observations on satellites, shuttle and ground based measurements of shuttle and satellites shows a far field vehicle glow exists in addition to the known observed surface glow on shuttle.

Particulates in the field-of-view can act as hot targets for infrared systems. This is true for particles on the order of 5 microns or larger. A large number of small particles can interfere over most wavelengths. Little data is available as to the degradation levels for given particle sizes and concentrations. Mie scattering is the predominant mechanism for particulate scattering.

2.8.2 Deposited Contaminants

The effect of deposited contaminants can be changes in transmittance, reflectance and solar absorptivity/emissivity.

The reflectance of UV systems has been shown to change as much as 10% at 1216Å for a deposit of only 20 angstroms of outgassed deposits. Ultraviolet optics are more sensitive in general to deposits than visible or infrared optics. Figure 2.8.2 is a sample of UV degradation obtained by Dr. R. Gause, NASA, MSFC. The presence of solar UV during deposition has also been observed to enhance the onset of deposition, the rate of deposition and to change the nature of the deposits. Therefore, sunlit surfaces that receive deposition are more susceptible than surfaces not exposed.

2.8.2.1 Transmission and Reflectance

Some data on transmission and reflectance degradation due to contaminant deposition is available from flight samples returned to earth. One such set of data was obtained from optics flown on Gemini XII. The true source of these deposits is not known. They are one of the few cases where detailed measurements were made. Figure 2.8.3 shows a spectral attenuation coefficient that was derived from contaminant thicknesses for transmission and reflectance. Other limited data on outgassed deposits and bipropellant engine deposits yielded an extinction coefficient that correlated to Fig. 2.8.3 within 30 to 50%. For very critical surfaces specific ground testing should be performed for sources that can deposit on the critical surfaces.

MATERIAL	THICKNESS RANGE (Å)	REFLECTANCE CHANGE (%)/Å AT 1236 Å		
		Specular (30°)	Forward (+45°)	Backward (-15°)
o Z-306 (POLYURETHANE)				
DEFT PRIMER	4-45	-1%		
	11-35		10%	
	37-41		25%	
9922 PRIMER	0-59	-.7%		
	72-133	-.5%		
	0-42		14%	
	58-120		6%	
	2-12			18%
	31-72			98%
o Z-302 WITH 9922	1-38	-.8%		
	5-33		27%	
	25-52			17%
o 401-C10 EPOXY	2-61	-.8%		
	8-45		29%	
	51-59		85%	
	8-17			50%
	23-37			27%
	52-60			13%
o CUTZOIL W5500	0-30	-1.4%		
	35-120	-.5%		
	4-119		.65%	
	3-115			.4%
o DIPCO 868 OIL	1.5-77	-.4%		
	1.5-77		.5%	
	1.5-77			.9%
o UNION LH4 OIL	50-117	-.3%		
	38-68		6%	
	71-88		11%	
	8-83			3%

FIGURE 2.8.2. OPTICAL DEGRADATION VS. CONTAMINATION THICKNESS

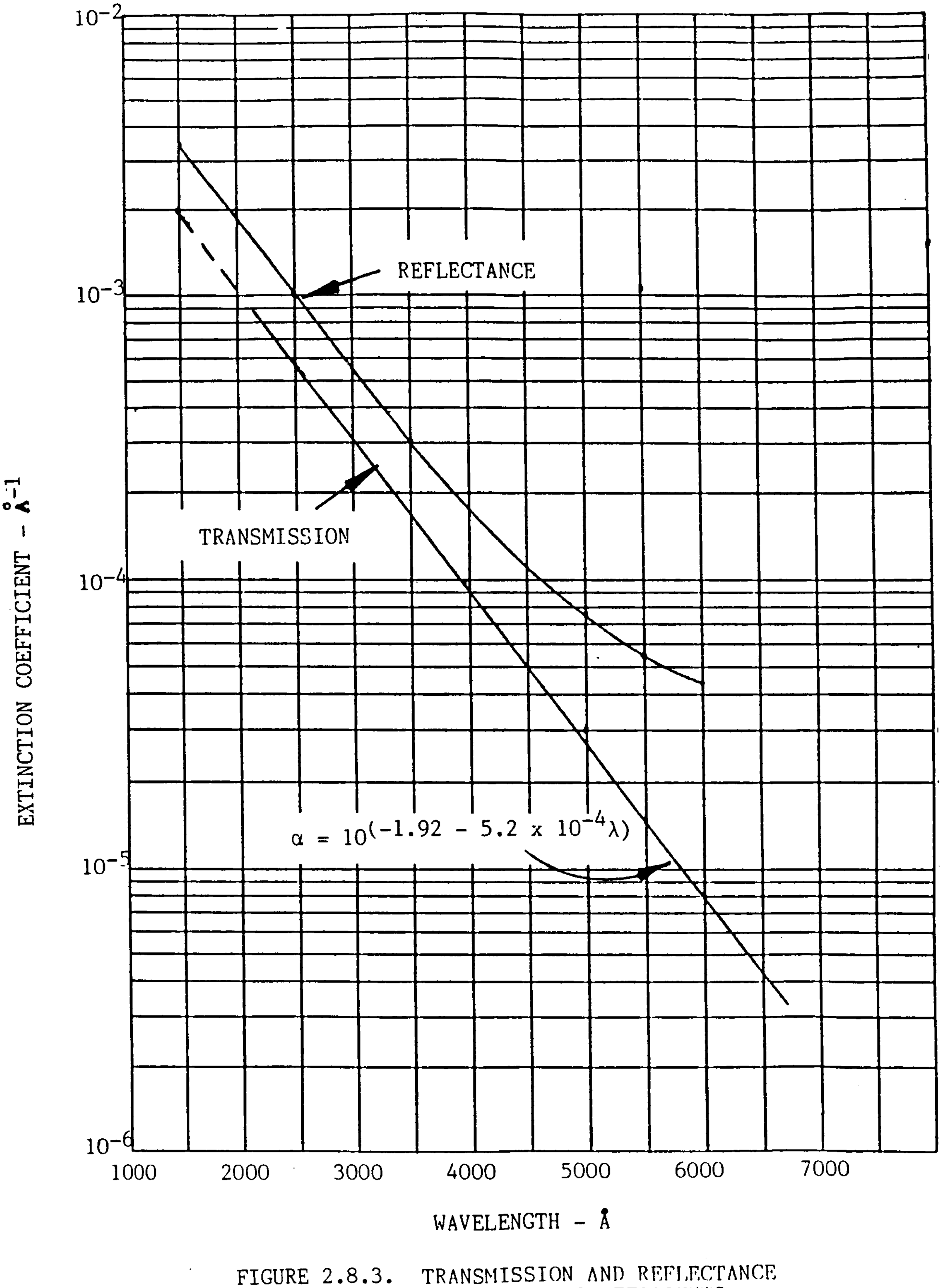


FIGURE 2.8.3. TRANSMISSION AND REFLECTANCE SPECTRAL EXTINCTION COEFFICIENTS

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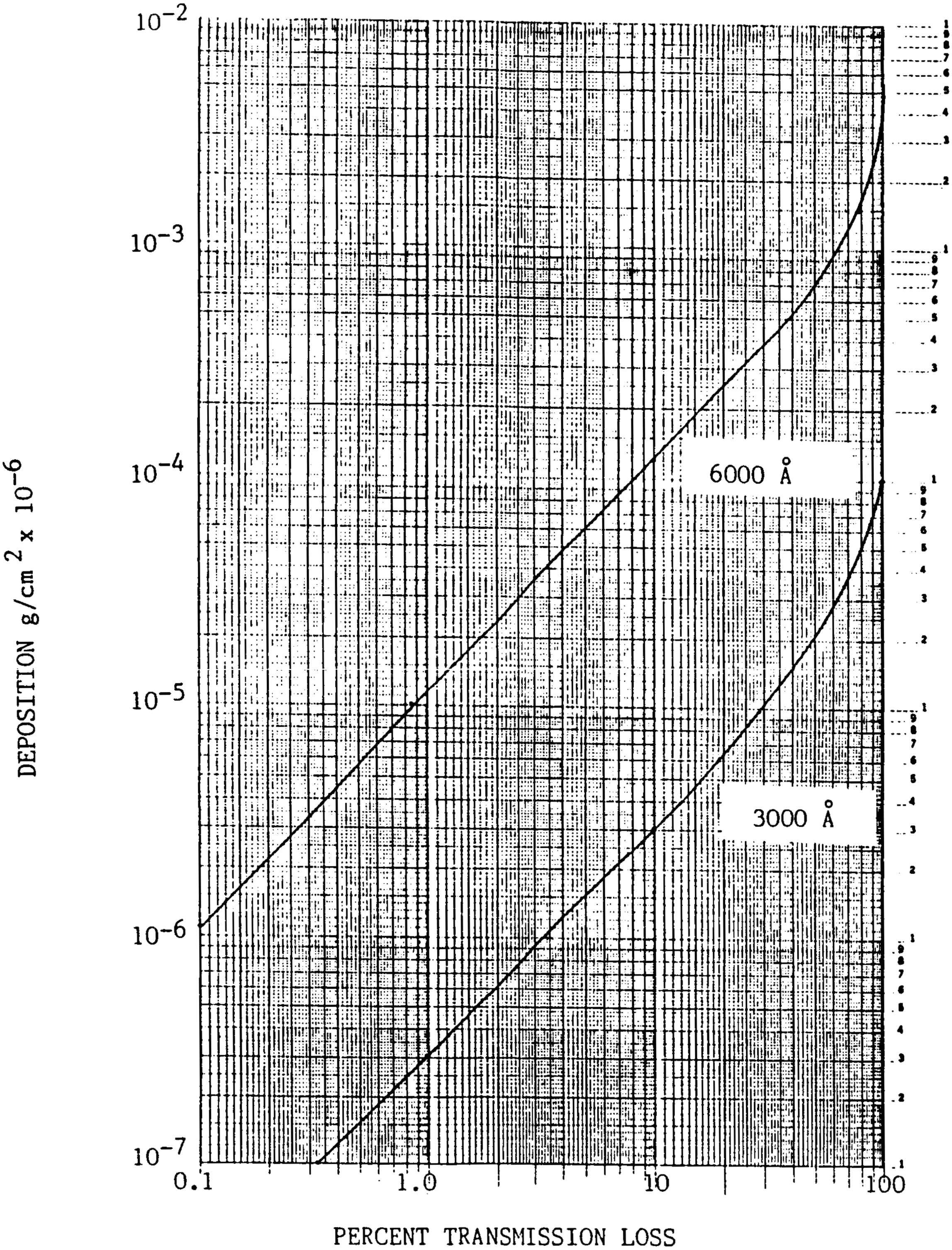

FIGURE 2.8.4. WINDOW TRANSMISSION LOSS DUE TO CONTAMINANT DEPOSITS FOR 3000 Å AND 6000 Å WAVELENGTH

2.8.2.2 Window Transmission Loss

The transmission attenuation shown in figure 2.8.3 can be plotted for specific wavelengths as a function of thickness. Two such examples are shown in Fig. 2.8.4 at wavelengths of 3000 and 6000 angstroms.

If the response of a system such as a solar array or the human eye is applied to a deposit for a given signal source then a power loss or brightness loss can be calculated. Figure 2.8.5 shows the percent brightness loss for a dark adapted human eye. This is important when windows or view ports become contaminated over a period of time.

2.8.2.3 Solar Absorptivity

Several sets of data on solar absorptivity changes have been generated from flight and laboratory testing.

Figure 2.8.6 shows the measured change in solar absorptivity for two types of white paint. Samples returned from Skylab had mass deposition estimates made by near mass monitors and model predictions. The samples were exposed to significant levels of solar UV and were yellow to tan color.

Figure 2.8.7 plots changes in solar absorptivity on S13G white paint obtained from ground engine tests at LeRC. UV was present during and after deposition.

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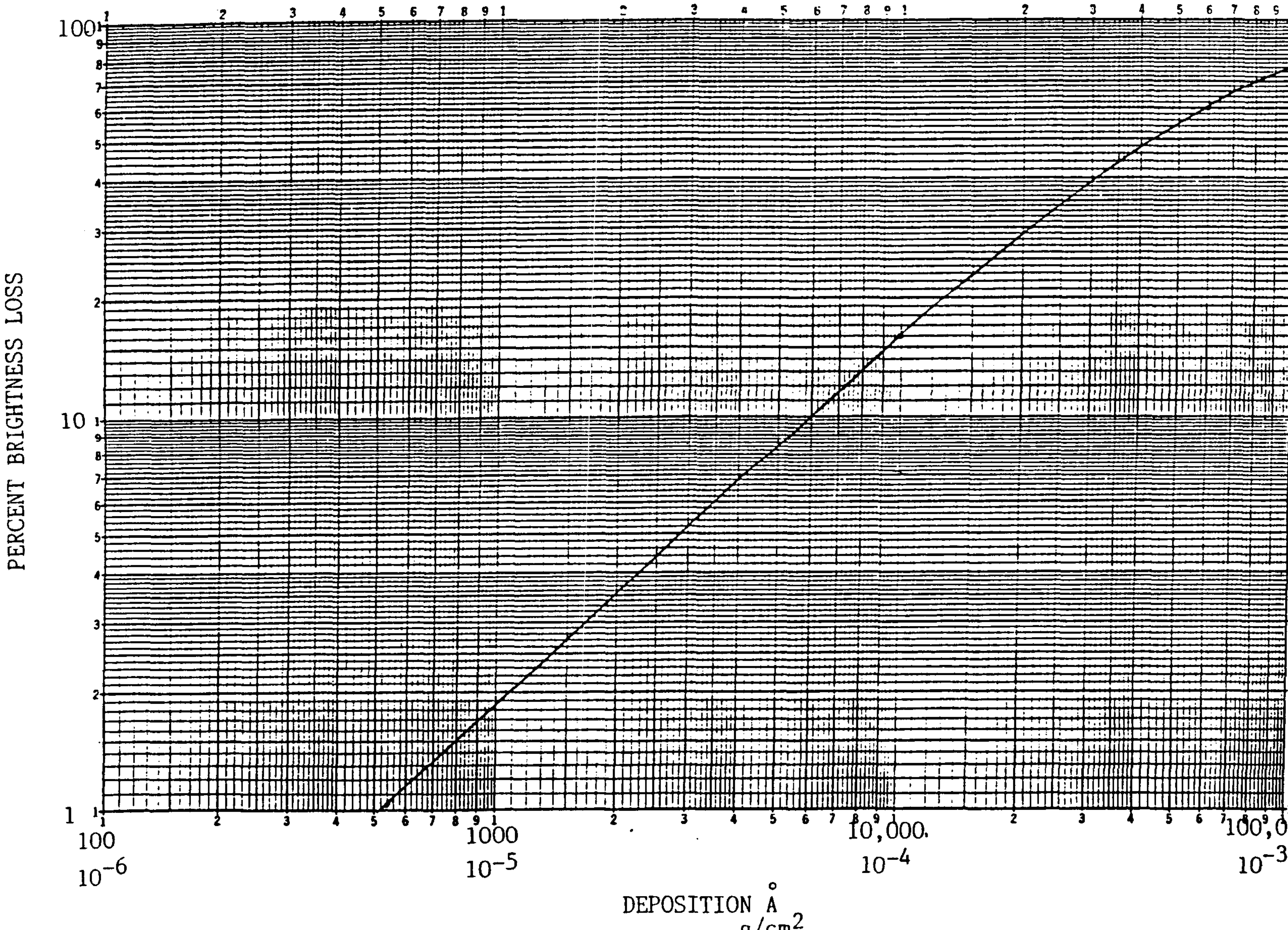


FIGURE 2.8.5. PERCENT BRIGHTNESS LOSS VERSUS DEPOSITION FOR A PHOTOPIC EYE RESPONSE

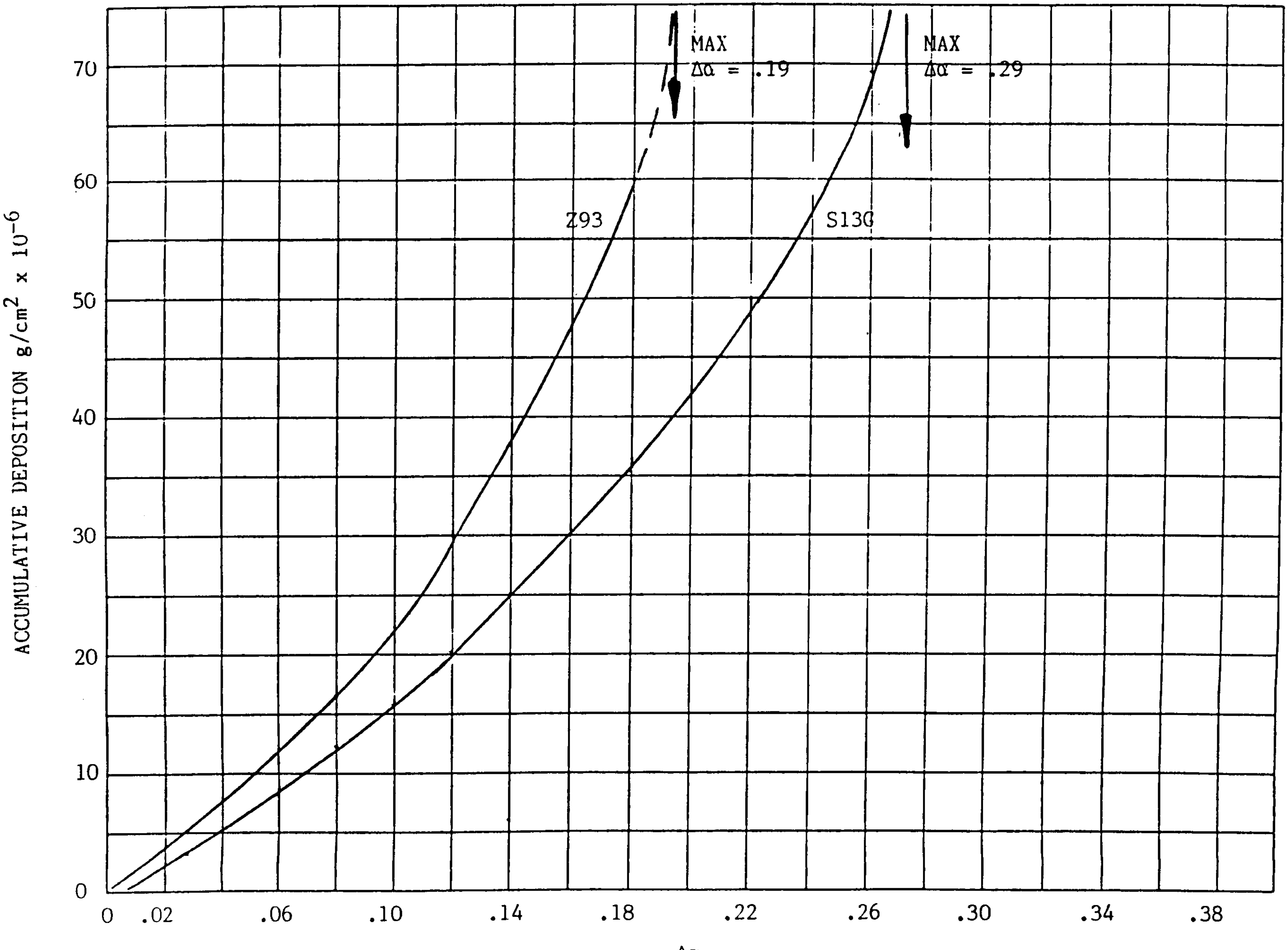


FIGURE 2.8.6. SOLAR ABSORPTIVITY ($\Delta\alpha s$) VERSUS DEPOSITION FOR SOLAR EXPOSURE

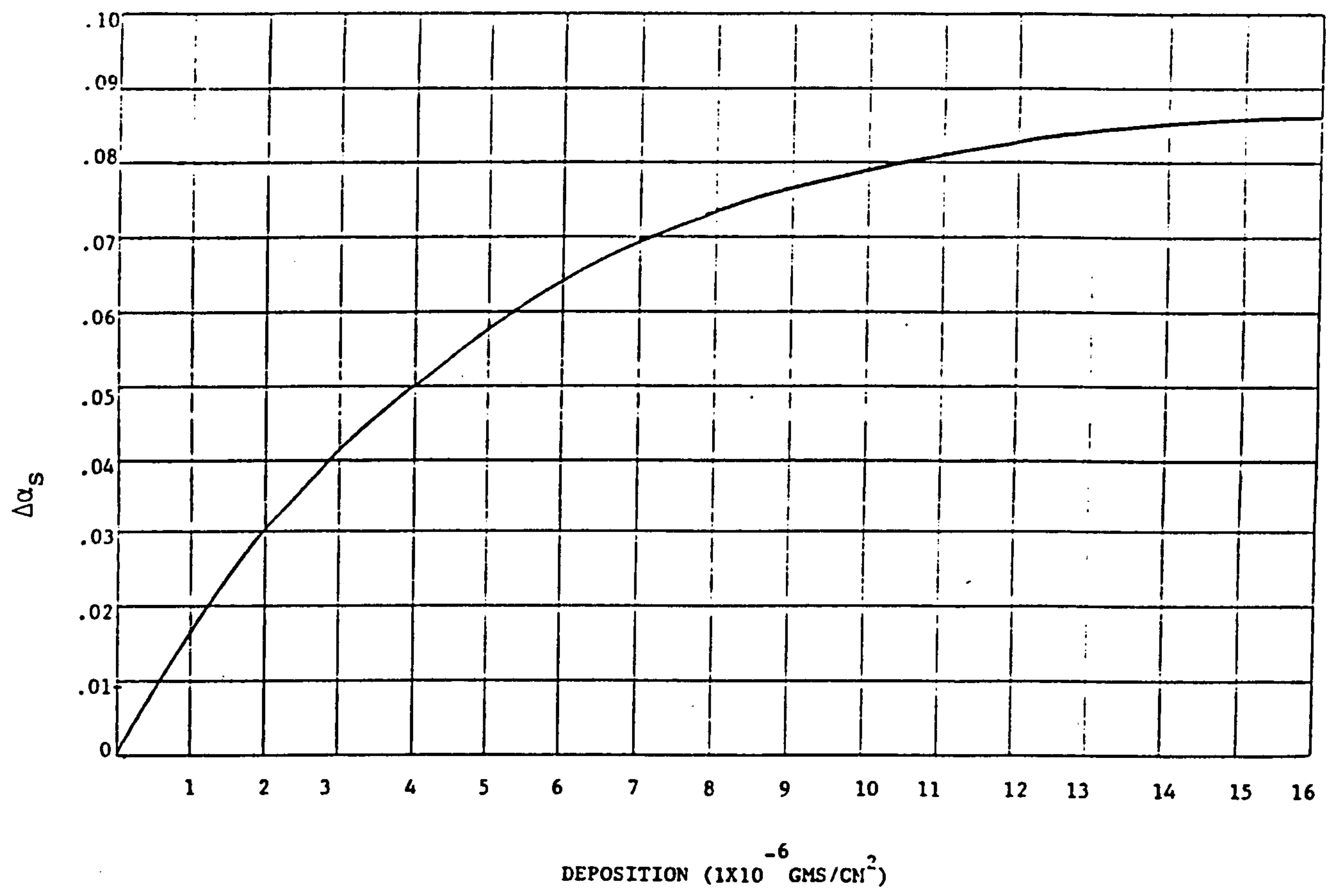


FIGURE 2.8.7. $\Delta\alpha_S$ CHANGE FOR BIPROPELLANT ENGINE EXHAUSTS DEPOSITS

2.8.3 Orbital Debris

Orbital debris that is man made is on the increase. These particles can cause serious damage to outer surfaces of payloads. A summary of the results measured to date can be found in NASA CP 2360. The amount of particulate debris will increase with increasing space launch activities.

Dr. Lubert Leger, NASA, JSC has utilized the orbital debris data to show that at space station altitudes surfaces experience significant impacts. His study showed that 400 impacts per meter squared, per year occur on a surface for debris particles in the size range of 0.01 to 0.5 mm diameter.

2.9 SPACE STATION SOURCES

The sources of contamination for space station are not much different than other manned systems such as Skylab and shuttle.

The external contamination sources will be both particulate and molecular and can contribute to both deposition and material within the line-of-sight of payload viewing.

Table 2.9.1 summarizes the sources and indicates whether they are continous or intermittent, controllable, or are capable of depositing.

TABLE 2.9.1 CONTAMINANT SOURCES FOR SPACE STATION PAYLOADS

MAJOR SOURCE	LOCATION	DURATION/ FREQUENCY	MAJOR CONSTITUENTS	CONTROLLABLE ?	LIKELY TO DEPOSIT
Outgassing	All external Space Station Surfaces	Continuous	Hydrocarbon chain fragments, RTV's Etc.,	No	Yes
Offgassing	All external Space Station Surfaces	Continuous- Decreases Quickly after vacuum ex- posure	Water, light atmosphere gases, volatiles	No	No
Pressurized volume atmosphere leakage	Pressurized modules	Continuous	O_2 - 22% N_2 - 75% CO_2- 1% H_2O- 2%	No	No
Vents	Aft of HAB. Modules	Low level continuously, higher rates during non operational periods	H_2O, N_2, O_2	Yes, but Limited duration	No
Air Locks	On pressure modules	Primarily during EVA initiation	Same as leakage	Yes	No
EVA	Astronaut	As RQD	Same as leakage, particulates from suit	No	No Yes
RCS	TBD	As RQD	H_2O	Limited	No
Gimbals	Solar Panels Same Payloads	Continuous to intermittent	Particulates	Limited	Maybe

TABLE 2.9.1 Continued

MAJOR SOURCE	LOCATION	DURATION/ FREQUENCY	MAJOR CONSTITUENTS	CONTROLLABLE	LIKELY TO DEPOSIT
Shuttle VCS engines	On Shuttle	During approach and seperation-variable	H_2O - 29.5% N_2 - 41.9% CO - 17% MMH-HNO_3 .2%	Limited	Yes
Also Shuttle - Outgassing - Offgassing - Leakage - Air locks - Etc.,	Variable	Variable	Close to same as Space Station	Limited	Only Outgassing & some particulate sources
OMU Free Fliers etc.,	TBD				

3.0 PAYLOAD SURVEY

In order to assess the impact(s) of the space station induced environment on OSSA/IOC payloads, a survey was conducted in an attempt to determine what levels of contamination each payload can tolerate and still maintain data integrity.

The following list of payloads plus key contact for each was given to SEA by OSSA planners.

Key Contact	Payload Name	Mission Code
William Robert	ASO/SOT Mission	SAAX010
	ASO/SOT Servicing	SAAX010A
	ASO/POT Mission	SAAX011
	ASO/POT Servicing	SAAX011A
	Cosmic Dust Collection Experiment	SAAX112
	Astrometric Telescope	SAAX115
	Solar-Terrestrial Observatory	SAAX207
	ACRIM	SAAX207A
	HRTS	SAAX207C
	SUSIM	SAAX207E
	SEPAC	SAAX207F
	WISP	SAAX207G
	TEBPP	SAAX207H
	Recoverable PDP (RPDP)	SAAX207J
	Solar-Terrestrial Polar Platform	SAAX225
	VCAP	SAAX225A
	AEPI	SAAX225B
	ISO	SAAX255C
	WAMII	SAAX225D

	MMP/CHEMSAT	SAAX225E
Thomas Campbell	Space-Based Antenna Test Range	SAAX502
Jim Welch	Hubble Space Telescope Servicing	SAAX012
Arthur Fuchs	AXAF Mission	SAAX017
	AXAF Servicing	SAAX017A
Dr. David Gilman	Space Station Hitchhiker 1	SAAX030
	Space Station Hitchhiker 2	SAAX031
	Space Station Hitchhiker 3	SAAX032
Dr. Dixon Butler	Mod. Res. Imaging Spectrometer - T	SAAX208
	High Res. Imaging Spectrometer (HIRIS)	SAAX209
	Laser Atmospheric Sounder and Alt. - A	SAAX211
	Synthetic Aperature Radar	SAAX212
	Altimeter	SAAX213
	Scatterometer	SAAX214
	Correlation Radiometer	SAAX215
	Earth Radiation Buget EXP-ERBE	SAAX216
	Magnetosphere Monitors	SAAX218
	Automated Data Collection/LOC Systems	SAAX220
	Earth Observing System (EOS)	SAAX202
	FABPV PERDT Interferometer	SAAX230
	Pressure Modulation Radiometer (PMR)	SAAX234
	Mod. Res. Imaging Spectrometer - N	SAAX239

	Special Sensor Microwave Imager	SAAX240
	LASA-R	SAAX241
	Advanced Microwave Sounding Unit	SAAX244
Donald Wrublik	Microgravity and Materials Processing Facility (MMPF)	SAAX401
Dr. Robert Schiffer	Hitchhiker 4 - Earth Radiation	SAAX250
William Hibbard	Explorer 2 Servicing	SAAX028
	Explorer 3 Servicing	SAAX029
Eugene Humphrey	Gamma Ray Observatory Servicing	SAAX013
Dr. Gerald North	Tropical Rainfall Mapping Mission	SAAX251
Dr. Jonathan Ormes	Cosmic Ray Nuclei Experiment	SAAX001
Kenneth Rosette	Explorer 1 (SMM) Servicing	SAAX027
Joseph Shulman	Space Station Spartan Mission	SAAX022
	Space Station Spartan Servicing	SAAX022A
Larry Manning	SIRTF Mission	SAAX004
	SIRTF Servicing	SAAX004A
Dr. Gary Musgrave	Life Sciences Lab	SAAX307

On 20 June 1986, a request-for-information (RFI) form (Fig. 3.1) was sent to each of the key contacts listed above. Of the sixteen original contacts, five gave names for further contact. These were:

1.) Dixon Butler	- John Gille (Upper Atmosphere Cryogenic Limb Device)
	- Greg Vane (HIRIS)
2.) William Roberts	- Art Walker (ASO)
	- Jack Kropp (STO)
3.) David Gilman	- Dan Spicer (SOT)
	- Fred Wittteborn (SIRTF)
4.) Kenneth Rosette	- James Moore (Space Telescope)
	- John Mather (COBE)
	- Donald Kniffen (GRO)
	- Stewart Jordan (SOT)
	- Carl Reber (UARS)
5.) Gary Musgrave	- Roger Arno (Life Sciences Lab)
	- Roger Michaud (Life Sciences Lab)

Each of the additional contacts was sent a RFI form for their respective payload. All RFI forms were sent on or before 1 July 1986. On 9 September 1986, telephone calls were made to those who: 1.) had not responded in any way to the RFI form and 2.) to those who had only responded in part to the total number of payloads they were designated as being the primary contact. Table 3.1 provides a summary of which payloads contacts responded to the RFI form.

REQUEST FOR INFORMATION

SPACE STATION ATTACHED PAYLOAD DATA FOR
USER CONTAMINATION REQUIREMENTS ASSESSMENT

EXPERIMENT: ______________________________

PAYLOAD NAME: ______________________ DESIGNATOR: ______________________

SPECTRAL OPERATING RANGE: ____________

P.I. NAME: ___________________________ PHONE: (___) ___-________ EXT: _______

ADDRESS: ___________________________ DATE: _____________

1.0 Identify any drawings or articles attached: ______________________

2.0 Location on Space Station (coordinates + verbal description): _______

3.0 Payload Size: ______________________________

4.0 Payload Weight: _______________

5.0 Operational Periods: ______________________________

6.0 EVA Visits, Duration, Frequency: ______________________________

7.0 Field of View of Critical Surfaces: ______________________________

8.0 Viewing direction of FOV relative to velocity vector (Space Station coordinates) ______________________________

9.0 Venting Requirements: ______________________________

FIGURE 3.1. REQUEST FOR INFORMATION FORM.

9.1 Active or passive vent locations: ______________________________

9.2 Active or passive vent flow rates/species (effluent types)/ temperatures: ______________________________

10.0 Externally exposed critical surface identification and operating temperature: ______________________________

11.0 Surfaces exposed during EVA: ______________________________

12.0 Operating temperature of thermal control surfaces or baffles: ______

13.0 Nearest neighbor payloads: ______________________________

14.0 Surfaces exposed to UV: ______________________________

15.0 Surfaces in Field of View of critical surfaces: ______________

16.0 Surface material in FOV of critical surfaces: ______________

17.0 Thermal/vacuum conditioning/handling prior to installation (temperature, time, instrumentation, etc.): ______________

18.0 External materials type: ______________________________

19.0 External surface temperatures: ______________________________

20.0 Final cleaning procedures and time prior to installation: ________

FIGURE 3.1. REQUEST FOR INFORMATION (CONTINUED)

21.0 Storage environment: ____
____
____
____

22.0 Active or passive shielding capability: ____________________________
____
____

23.0 Thermal heating capability of critical surfaces: ____________________
____

24.0 Sensitivity of surfaces to atomic oxygen: ___________________________
____
____

25.0 Sensitivity of critical surfaces to molecular deposition: __________
____
____

26.0 Sensitivity of critical surfaces to deposited particles: ___________
____
____

27.0 Sensitivity to particles in FOV - size, number, frequency: __________

____
____

28.0 Sensitivity to gases in FOV by species: ____________________________
____
____

29.0 Sensitivity to background brightness - wavelength and intensity: ____
____
____

__________________________ Date: __________
Principal Investigator

FIGURE 3.1. REQUEST FOR INFORMATION (CONTINUED)

Table 3.1 RFI Response Summary

PAYLOAD CONTACT	PAYLOAD NAME	RESPONSE TO RFI
William Hibbard	Explorer 2 Servicing	NO
	Explorer 3 Servicing	NO
Eugene Humphrey	Gamma Ray Observatory	YES
Dr. Gerald North	Tropical Rainfall Mapping	YES
Dr. Jonathan Ormes	Cosmic Ray Nuclei Experiment	NO
	Superconducting Magnet Facility	YES
Kenneth Rosette	Explorer 1 Servicing	NO
Joseph Shulman	Space Station Spartan Mission	NO
	Space Station Spartan Servicing	NO
Larry Manning	SIRTF Mission	YES
	SIRTF Servicing	YES
Roger Arno	Life Sciences Lab	NO
Roger Michaund	Life Sciences Lab	NO
Jim Welch	Hubble Space Telescope Servicing	NO
Arthur Fuchs	AXAF Mission	NO
	AXAF Servicing	NO
Dr. David Gilman	Space Station Hitchhiker 1	NO
	2	NO
	3	NO
Dr. Dixon Butler	Mod. Res. Imaging Spectrometer-T	No
	High Res. Imaging Spectrometer	YES
	Laser Atmospheric Sounder and Alt.-A	NO
	Synthetic Aperature Radar	NO
	Altimeter	NO

	Scatterometer	NO
	Correlation Radiometer	NO
	Earth Radiation Buget EXP-ERBE	NO
	Magnetosphere Monitors	NO
	Automated Data Collection/LOC	NO
	Earth Observing System	NO
	FABRV PERDT Interferometer	NO
	Pressure Modulation Radiometer	NO
	Mod. Res. Imaging Spectrometer - N	NO
	Special Sensor Microwave Imager	NO
	LASA-R	NO
	Advanced Microwave Sounding Unit	NO
Donald Wrublik	Microgravity & Materials Processing Facility	YES
Dr. Robert Schiffer	Hitchhiker 4 - Earth Radiation	NO
William Roberts	ASO/SOT Mission	NO
	ASO/SOT Servicing	NO
	ASO/POF Mission	NO
	ASO/POF Servicing	NO
	Cosmic Dust Collection	NO
	Astrometric Telescope	YES
	Solar-Terrestrial Observatory	YES
	Solar-Terrestrial Polar Platform	NO
John Gille	Upper Atmosphere Cryogenic Limb Device	NO
Greg Vane	HIRIS	YES
Art Walker	ASO	NO
Jack Kropp	Solar-Terrestrial Observatory	YES

Dan Spicer	ASO	NO
Fred Witteborn	SIRTF	YES
James Moore	Space Telescope	NO
John Mather	COBE	NO
Donald Kniffen	GRO	NO
Stewart Jordan	SOT	NO
Carl Reber	UARS	NO

Table 3.2 summarizes those RFI forms which were returned to SEA completed.

TABLE 3.2 RFI DATA SUMMARY

PAYLOADS

RFI QUESTIONS	SIRTF MISSION SIRTF SERVICING SAAX 004 & A	SUPERCONDUCTING MAGNET FACILITY SAAX 021	ASTROMETRIC TELESCOPE SAAX 115	HIRIS SAAX 209	TROPICAL RAINFALL MAPPING SAAX 251
1. Identify any drawings or articles attached	Drawings Provided	3 Sketches Provided	Drawings Provided	Conceptual Designs	Color Photo
2. Location on Space Station (coordinates & verbal description)	Free Flying	Upper boom (dual keel)	Upper Vertical boom (dual keel)	EOS platform 2 carrier position TBD	Horizontal truss closest to Earth
3. Payload Size	10.9m	4m diameter 9m length, cylinder	22 meters 2 meter diameter	2.81x1.83x1.83m	6x8x4m
4. Payload Weight	5560 Kg	5000 Kg	5700 Kg	1080 Kg	350 Kg
5. Operational Periods	None at Space Station	Continuous	TBD	TBD	Continuous
6. EVA Visits, Duration, Frequency	Every 2 years 2, 2-man 6hr. EVA's	5hrs. semiannually	No regular servicing required	4.25hrs/EVA Frequency TBD	One visit 3-5yrs.
7. Field of View of Critical Surfaces (FOV)	All critical surfaces will be covered during surfacing	90x120°	± 4.5°	TBD	TBD
8. Viewing Direction of FOV Relative to Velocity	90°	Both fields are zenith pointing	NADIR to 10° aft	+60°/-30° fore/aft +20°/-20° cross track	Conical scanning ±70° (left & right of velocity vector at a 50° constant NA!
9. Venting Requirements	6.4mg/sec He @250K	LHe boil-off 7.0 liter/day	none	TBD	None
9.1 Active or Passive Vent Locations	Not Provided	TBD	None	TBD	NA
9.2 Active or Passive Vent Flow Rates/Species (effluent types)/Temperature	Not Provided	TBD	None	TBD	NA
10. Externally exposed critical surface identification & operating temperature	200K	None	450K - sun side 100K - dark side 290K - baffles	TBD	$4x7_m$ Al or Graphite antenna 300K

TABLE 3.2 RFI DATA SUMMARY (CONTINUED)

11. Surfaces exposed during EVA	surfaces will be capped	None	None	TBD	Antenna
12. Operating temperature at thermal control surfaces or baffles	300 K	None	290K - baffles 0° - radiator	Detector 150K	300K
13. Nearest neighbor payload	Unknown	1m for servicing Clearance TBD	TBD	TBD	AVHRR
14. Surfaces exposed to UV.	all external surfaces	None	Thermal Blankets	TBD	None
15. Surfaces in FOV of critical surfaces	All critical surfaces covered except outer shell	None	None	TBD	NA
16. Surface material in FOV of critical surfaces	Unknown	None	Al, black paint Graphite Epoxy Sealer	TBD	NA
17. Thermal/vacuum conditioning/handling prior to installation	TBD	None	None	TBD	200-350°K
18. External material types	MLI White Paint	Conventional thermal control materials	Thermal Blankets	TBD	Al & Graphite epoxy
19. External surface temperatures	200-250K Telescope 200-250K dewar 300K Spacecraft	TBD	same as 10 & 12	TBD	300 K
20. Final Cleaning procedures & time prior to installation	Unknown	TBD	As required	TBD	None
21. Storage environment	Class 10K	No special requirements	Clean room bagged	Continous N_2 purge	200-350°K
22. Active or Passive Shielding	For critical surfaces	Debris shield	Active Aperature Cover	None	Thermal blankets
23. Thermal heating capability of critical surfaces	300 K	None	Only radiator	None	TBD
24. Sensitivity of surfaces to atomic oxygen	Tolerant to prolonged exposure	None	Graphite Epoxy	TBD	None
25. Sensitivity of critical surfaces to moleculor deposition		None	Mirror TBD amount Detector TBD amount	mirror <0.005 thermal surfaces <0.15	None

TABLE 3.2 RFI DATA SUMMARY (CONTINUED)

26. Sensitivity of critical surfaces to deposited particles	Class 300	None	Detector TBD amount	Mirror <300 per MIL-STD 1246A	None
27. Sensitivity to particles in FOV (size, number, frequency)	1 particle μ/orbit/10-5 steradian	None	TBD	TBD	None
28.	None during service. On-Orbit 10^{11} molecules/cm^2 for each of H_2O, CO_2 and all other IR emitters. 10^{13} molecules/cm^2 for each of O_2, N_2 H_2	None	None	TBD	None
29.	None during service. λ Recommended 1 1.0×10^{-11} 5 5×10^{-11} 10 4×10^{-11} <30 1×10^{-11} >30 6×10^{-12} 300 3×10^{-13} λ maximum 1 1×10^{-10} 5 1×10^{-10} 10 2×10^{-10} <30 4×10^{-11} >30 3×10^{-11} 300 1×10^{-11} Units are in watt $m^{-2} sr^{-1} nm^{-1}$	None	None	TBD	None

3.1 SUMMARY/CONCLUSIONS

OSSA provided SEA with a list of approximately 40 payloads for which they felt it was necessary to evaluate during this study. RFI forms were sent to each payload contact with a letter explaining why we were requesting the information. Of those RFI forms that were sent, only 5 forms were returned to SEA with the questions answered.

Based on the data shown in Table 3.2 one can readily see how little contamination is understood by most payload specialists. For example, question 19 of the RFI form asks about the types of materials that will be used on external surfaces. The response given for the Superconducting Magnet Facility was, "conventional thermal control materials." Conventional thermal control materials consist of kapton blankets and white paints. Both of these materials are susceptible to atomic oxygen and molecular deposition. However, the response to the questions which specifically address the areas of atomic oxygen and molecular deposition susceptibility was "none." These types of responses, together with the fact that less than 1% of all the RFI forms sent were returned with data make it difficult to assess the impacts of the total interaction of space station and STS with OSSA payloads.

We knew from the outset of this study that many of the questions contained in the RFI form may not have answers at this stage in the Space Station program. However, it was our intent to create an awareness within the OSSA payload community of contamination issues and their potential impacts on each payload.

4.0 CONTAMINATION REQUIREMENTS - JSC 30426

The space station external contamination control requirements that were modified as a result of an Aug. 13-14, 1986 Contamination Control Working Group meeting are presented here for reference. These will essentially be part of space station requirements for Phase C/D studies. The input to this working group during this study are discussed in detail in section 5.1.3.

JSC 30426

CONTAMINATION REQUIREMENTS

ABBREVIATIONS AND ACRONYMS

ASTM	American Society for Testing and Materials
cm	Centimeter
g	Gram
IR	Infrared
JSC	Johnson Space Center
MCD	Molecular Column Density
MIL	Military
PMP	Prime Measurement Point
SSCBD	Space Station Control Board Directive
STD	Standard
STS	Space Transportation System
TBD	To Be Determined
UV	Ultraviolet
VCM	Volatile Condensable Material

CONTAMINATION. Any effect arising from the induced environment gaseous, particulate, or light background that interferes with or degrades the results of the intended measurement or that degrades Space Station component and payload experiment hardware such that refurbishment is required before continued use.

DEPOSITION--MASS. The mass of contaminant collected by a unit area of a surface. The deposition process depends on the incident mass flux of the contaminant, the surface temperature, solar exposure, and the properties of the surface and the contaminant. Mass deposition units are g/cm^2.

DEPOSITION--THICKNESS. The thickness of contaminant collected on a surface. Since the deposition is not typically uniform, this quantity is usually an average. It is then related to mass deposition by the density of the contaminant. Deposition thickness units are cm or Angstrom ($1 Å = 10^{-8}$ cm).

INDUCED ENVIRONMENT. The molecular, particulate, and photon environment in the vicinity of and created by the presence of the Space Station. Ambient atmospheric perturbations which are caused by spacecraft flight and create wake/ram effect are covered in this definition.

MAIN CLUSTER SPACE STATION. That part of the Space Station which contains pressurized modules, servicing facilities, and regions on the the upper and lower booms dedicated to astronomical and Earth viewing.

MOLECULAR COLUMN DENSITY (MCD). The integral of the number density (number of molecules of a particular species per unit volume) along a specified line of sight originating from one of the Prime Measurement Points (PMP)'s. MCD unit is $number/cm^2$.

NONQUIESCENT TIME INTERVALS. Periods when some of the requirements specified herein do not have to be met and measurements may be perturbed by the induced environment to the extent described in this document.

PAYLOAD. Space Station user specific hardware.

PRIME MEASUREMENT POINT (PMP). Locations on both the Earth and astronomical observing regions of the Station cluster representative of the location of entrance apertures of instruments for use in modeling the induced environment.

QUIESCENT TIME INTERVALS. Periods when minimum perturbations to the environment occur; generally, this includes all times except such activities as Space Transportation System (STS) docking and undocking, and periodic reboost.

SPACE STATION PLATFORMS. Independent, free flier portion of Space Station.

SPACE TRANSPORTATION SYSTEM (STS). Delivery vehicle for Space Station elements and payloads.

SPECTRAL IRRADIANCE. The radiant energy incident on a unit area per unit time from a unit solid angle within unit spectral interval.

1.0. SCOPE

This document contains the requirements for the induced, external, gaseous, light, and particulate environment of the Space Station and its elements that are necessary to ensure maximum utilization of Station capabilities. The requirements are derived from previous experience bases and should therefore be achievable at minimum program costs if they are considered early in design. These requirements reflect the maximum levels of induced environment that can be tolerated in order to make measurements without induced atmospheric perturbations for all presently known attached users except some atmospheric composition studies. Requirements as stated are applicable for Station elements including payloads. Although the requirements as stated are primarily driven by user needs, Space Station component requirements have been considered and are included when these components are the most sensitive. Requirements applicable to Shuttle delivery to space and return are also included.

2.0. DOCUMENTS

2.1. APPLICABLE DOCUMENTS

2.1.1. MIL-STD-1246A, Military Standard Product Cleanliness Levels and Contamination Control Program

2.1.2. Johnson Space Center (JSC) SN-C-0005B, Specification, Contamination Control Requirements for the Space Shuttle Program

2.1.3. ASTM E595, Standard Test Method for Total Mass Loss and Collected Volatile Condensable Materials from Outgassing in a Vacuum Environment

2.2. REFERENCE

JSC 30233, Space Station Requirements for Materials and Processes

3.0. REQUIREMENT APPLICABILITY

3.1. MAIN CLUSTER SPACE STATION

3.1.1. TEMPORAL

The induced environment associated with the core Station will be strongly influenced by activities associated with its operation. For example, the induced environment will be increased during Shuttle docking and periodic Space Station reboost. It is prudent, therefore, for specification of the induced environment contamination requirements to define two conditions of the induced environment, quiescent periods, and disturbed or nonquiescent periods. Quiescent periods provide minimum induced environment and maximum measurement capability, and all the requirements of this document are applicable. For nonquiescent periods, it is assumed that the disturbed environment will generally be unacceptable for some measurements; however, the environment must not produce conditions that preclude returning to operational measurements as soon as the disturbing activity is terminated. Requirements stated in paragraph 4.5.1 are not applicable during nonquiescent periods. Disturbing activities leading to nonquiescent periods should be of short duration resulting in most of Space Station time being quiescent. Generally, environmental conditions as stated in paragraph 4.5.1 shall be maintained for up to 14 days during required viewing periods. Nonquiescent periods shall not exceed TBD percent of Station time.

3.1.2. GEOMETRIC CONSIDERATIONS

Requirements as outlined in section 4.0 are applicable to all regions around the main Space Station cluster.

3.2. PLATFORMS

3.2.1. TEMPORAL

Platforms require servicing periodically, and it is reasonable to assume that not all measurements will be possible during associated operations. It is convenient to also separate platform requirements into quiescent and nonquiescent categories. The same connotation and applicability as used for the main cluster considerations apply.

3.2.2. GEOMETRICAL

TBD--Dependent on each platform requirements.

4.0. REQUIREMENTS

4.1. CONTAMINATION CONTROL PLAN

A Space Station Contamination Control Plan defining the implementation methods, controls, and responsibilities which are necessary to ensure the requirements are met shall be generated.

4.2. MANUFACTURING AND MATERIALS

Two requirements apply to the manufacturing phase of both the Space Station components and user equipment. First, all hardware external surfaces shall be cleaned as a minimum to level 750 as defined in MIL-STD 1246A prior to final assembly for delivery to space. Second, all materials used on hardware of any type including platforms, which will be exposed to space vacuum during the operational phase, must have low outgassing characteristics as defined by a total mass loss of $\leq$ 1.0 percent and a Volatile Condensable Material (VCM) of $\leq$ 0.1 percent, when tested per ASTM-E595. (See also Space Station Requirements for Materials and Processes, JSC 30233, paragraph 3.2.7.) Since airlocks are periodically depressurized, all materials used in the airlocks also must be selected for low outgassing.

Materials used in critical areas such as window compartments, solar dynamic collectors, or large surface areas such as servicing facilities must have outgassing characteristics compatible with deposition requirements and may have to be selected to more severe outgassing requirements than stated above. Off-the-shelf hardware will be screened for outgassing characteristics using TBD evaluation procedures.

4.3. SHUTTLE DELIVERY OF STATION COMPONENTS AND USER HARDWARE

For the purpose of Shuttle integration and space delivery, Station hardware will be cleaned to the standard level as defined in JSC-SN-C-0005 as a minimum. (Requirements of paragraph 4.2 will be adequate to satisfy this requirement.) Generally, the same requirements will be applicable for user hardware: however, more stringent requirements as defined in JSC-SN-C-0005 or MIL-STD 1246A (as referred to in paragraph 4.2) can be selected on an individual mission basis.

4.4. AMBIENT ATMOSPHERE/SURFACE INTERACTIONS

As Space Station flies through the Earth's rarefied environment, a ram-wake effect is created, i.e., pressure build-up occurs on forward facing surfaces and a pressure decrease occurs on aft facing surfaces. Pressure build-up on surfaces which have some exposure to ram can be as large as one to two orders of magnitude higher than the ambient pressure. Instruments which are sensitive to such pressure effects should be carefully located relative to large surfaces to preclude interference. Change in composition of the surface local environment can be expected due to either reaction with the surface or recombination occurring on or near the surface.

4.5. MAIN CLUSTER SPACE STATION AND PAYLOADS

4.5.1. QUIESCENT PERIODS

4.5.1.1. BACKGROUND SPECTRAL IRRADIANCE

The total Ultraviolet (UV) and visible radiation background from spacecraft-induced particulate and molecular scattering and emission must be less than the envelope defined by the spectral irradiances in table 4-1. For the Infrared (IR), the background intensity must be spatially and temporally uniform with a maximum variation of 1.1 X 10^{-13} watts m^{-2} sr^{-1} nm^{-1} per degree and 5.5 X 10^{-14} watt m^{-2} sr^{-1} nm^{-1} per second from 5 micrometers to 30 micrometers and 1.1 X 10^{-12} watt m^{-2} sr^{-1} nm^{-1} per degree and 5.5 X 10^{-13} watts m^{-2} sr^{-1} nm^{-1} per second above 30 micrometers. To achieve this, the background spectral irradiance must be held below the envelope shown in table 4-2. The maximum allowed value applies only if the background is temporally and spatially uniform enough to meet the stated requirements. The recommended values are based on a best estimate of the anticipated spatial variations.

4.5.1.2. MOLECULAR COLUMN DENSITY (MCD)

The induced MCD along any payload line of sight shall not exceed the following:

4.5.1.2.1. 1 X 10^{11} molecules/ cm^2 each for H20, for C02 and for all other IR emitting molecules (total not to exceed 3 X 10^{11} molecules/cm^2)

4.5.1.2.2. 1 X 10^{13} molecules/ cm^2 each for 02 for N2, for H2, for noble gases and for all other UV and non-IR active molecules combined (total not to exceed 5 X 10^{13} molecules/cm^2)

4.5.1.3. PARTICULATE BACKGROUND AND DEPOSITION

4.5.1.3.1. PARTICULATE BACKGROUND

Release of particles from main cluster Space Station shall be limited to one particle 5 microns or larger per orbit per 1 X 10^{-5} steradian field of view as seen by a 1 meter diameter aperture telescope.

Control of particles less than 5 microns in size shall meet TBD requirements.

4.5.1.3.2. PARTICULATE DEPOSITION

TBD

4.5.1.4. MOLECULAR DEPOSITION

The flux of molecules emanating from the core Space Station must be limited such that:

4.5.1.4.A. The mass deposition rate on two 300^{0} K surfaces both located at the PMP with one perpendicular to the +Z axis and the other whose surface normal lies in the horizontal plane and at critical power locations with an acceptance angle of 2 π steradian shall be no more than 1×10^{-14} g/cm^2 sec (daily average).

4.5.1.4.B. The mass deposition rate on a 300^{0} K surface located at the PMP and perpendicular to the Z axis with an acceptance angle of 0.1 steradian shall be no more than 1×10^{-16} g/cm^2 sec (daily average).

4.5.1.4.C. The mass deposition rate on a 5^{0} K surface located at the PMP and perpendicular to the Z axis with an acceptance angle of 0.1 steradian shall be no more than 2×10^{-13} g/cm^2 sec (daily average) excluding condensation of atmospheric constituents.

4.5.2. NONQUIESCENT PERIODS

4.5.2.1. MOLECULAR DEPOSITION

Total deposition on sensitive surfaces such as solar arrays or either the astronomy or Earth resources observation regions shall not exceed 4×10^{-7} g/cm^2 yr.

4.5.2.2. PARTICULATE DEPOSITION

TBD

4.6. PLATFORMS

This section will be completed when primary measurement requirements are derived. For preliminary design purposes, the platform contamination environment shall meet the requirements stated in paragraphs 1.0 through 5.0 herein as a minimum. Each platform mission shall define specific requirements in a Platform Contamination Control Plan.

4.7. EXTERNAL SERVICING

Spacecraft and instrumentation will be serviced external to the Station's pressurized environments in a partially enclosed but unpressurized area. Requirements associated with this servicing area include particulate deposition rates of TBD g/cm^2 sec and molecular deposition rates of 1×10^{-13} g/cm^2 sec (daily average) as measured on a 300° K surface with an acceptance angle of 2π steradian. During transfer of payload components from external to internal areas, component cleanliness levels shall be maintained.

TABLE 4-1. ULTRAVIOLET (UV) AND VISIBLE SPECTRAL IRRADIANCES

WAVELENGTH (nm)	BACKGROUND SPECTRAL IRRADIANCE AT 90^{o} SUN ANGLE (watts m^{-2} sr^{-1} nm^{-1})
121.6	TBD
155	3.5×10^{-11}
191	1.9×10^{-11}
246	1.3×10^{-11}
298	5.9×10^{-11}
332	1.0×10^{-10}
425	2.5×10^{-10}
550	2.0×10^{-10}
1000	1.0×10^{-10}

TABLE 4-2. INFRARED BACKGROUND SPECTRAL IRRADIANCE

WAVELENGTH (Micrometers)	RECOMMENDED SPECIAL IRRADIANCE (watts m^{-2} sr^{-1} nm^{-1})	MAXIMUM SPECTRAL IRRADIANCE (UNIFORM BACKGROUND) (watt m^{-2} sr^{-1} nm^{-1})
1	1.0×10^{-10}	1.0×10^{-10}
5	5.0×10^{-11}	1.0×10^{-10}
10	4.0×10^{-11}	2.0×10^{-10}
≤ 30	1.0×10^{-11}	4.0×10^{-11}
≥ 30	6.0×10^{-12}	3.0×10^{-11}
300	3.0×10^{-13}	1.0×10^{-11}

5.0. VERIFICATION AND MONITORING OF THE ENVIRONMENT

In addition to measurements related to verification of Space Station performance to the requirements contained in this document, monitoring of the environment to a limited extent will be required. Verification and monitoring measurement requirements shall consider background spectral irradiances, molecular and particulate deposition, released particulate, gas density and composition, local and directional pressure, gas column density, and returned gas flux.

End of Contamination

Control Document JSC 30426

5.0 ACTION ITEM/TRADE SUMMARY

Throughout the study major issues surfaced in the NASA community. Several of these had contamination impacts and SEA was asked to support them. These are summarized here along with the end results of each task.

5.1 CONTAMINATION CHANGE REQUEST SUPPORT FOR DUAL KEEL

This task originated in late July when it was determined that an updated contamination requirements set, in JSC 30000, was required for presentation to the appropriate level B review boards. SEA reviewed the existing contamination requirements and updated wherever possible. Contacts were made with payload personnel and scientists at NASA centers. Literature reviews were also performed to find any updated analysis that was applicable.

The issue of venting was also assessed by SEA. The results of the venting study is presented in the following sections.

Section 5.1.4 summarizes the presentations made for the contamination Requirements Change Request.

5.1.1 <u>Venting</u>

With the exception of engine firings, probably no contamination source needs to be more carefully analyzed than waste venting. Venting has the potential to produce very high concentrations of optically and chemically active contaminants over large volumetric regions. Consequently, it is extremely important to correctly model venting so that contaminated regions can be identified, evaluated, and if necessary avoided.

In an effort to maintain control both spatially and time wise over the venting of wastes on the dual keel configuration of space station, a single common vent was proposed by JSC. The common vent was placed at the wake end of the habitation modules (see Figure 5.1.1). In order to evaluate the contamination effects produced by a common vent, JSC modeled the vent as shown in Figure 5.1.2. Based on their vent model, JSC determined volumetric regions where contaminant levels were acceptable or unacceptable. Volumes with acceptable number column densities were designated Region 1 volumes. Volumes with unacceptably high number column densities were designated Region 2 volumes.

Unfortunately, the JSC vent modeling was overly simplistic and based on several erroneous initial assumptions. The JSC modeling effort assumed a free molecular flow within the nozzle, which lead them also to assume that the vent plume would retain the shape of the nozzle indefinitely. Based on these assumptions, JSC ignored the possibility of backflow (molecules which are scattered by the nozzle walls and each other out of the trajectory confines defined by the nozzle walls).

In order to more correctly evaluate the contamination effects of the common vent concept, backflow must be considered. Figure 5.1.3 shows three different nozzle configurations which were analyzed and tested by AEDC. As shown in the test matrix, the nozzles were tested at several different stagnation pressures and temperatures. The constant flow angles and constant number density lines are shown in Figure 5.1.4 for nozzle b. From this figure it is clear that the backflow from such a nozzle is quite significant. Analysis of the AEDC data allowed scaling of the AEDC results to the JSC nozzle configuration. The mass flux rates along two lines of sight from the payload locations were calculated. The two lines of sight are depicted in Figure 5.1.1 as dashed lines. The calculated mass flux rates for the two lines of sight are shown in Figure 5.1.5.

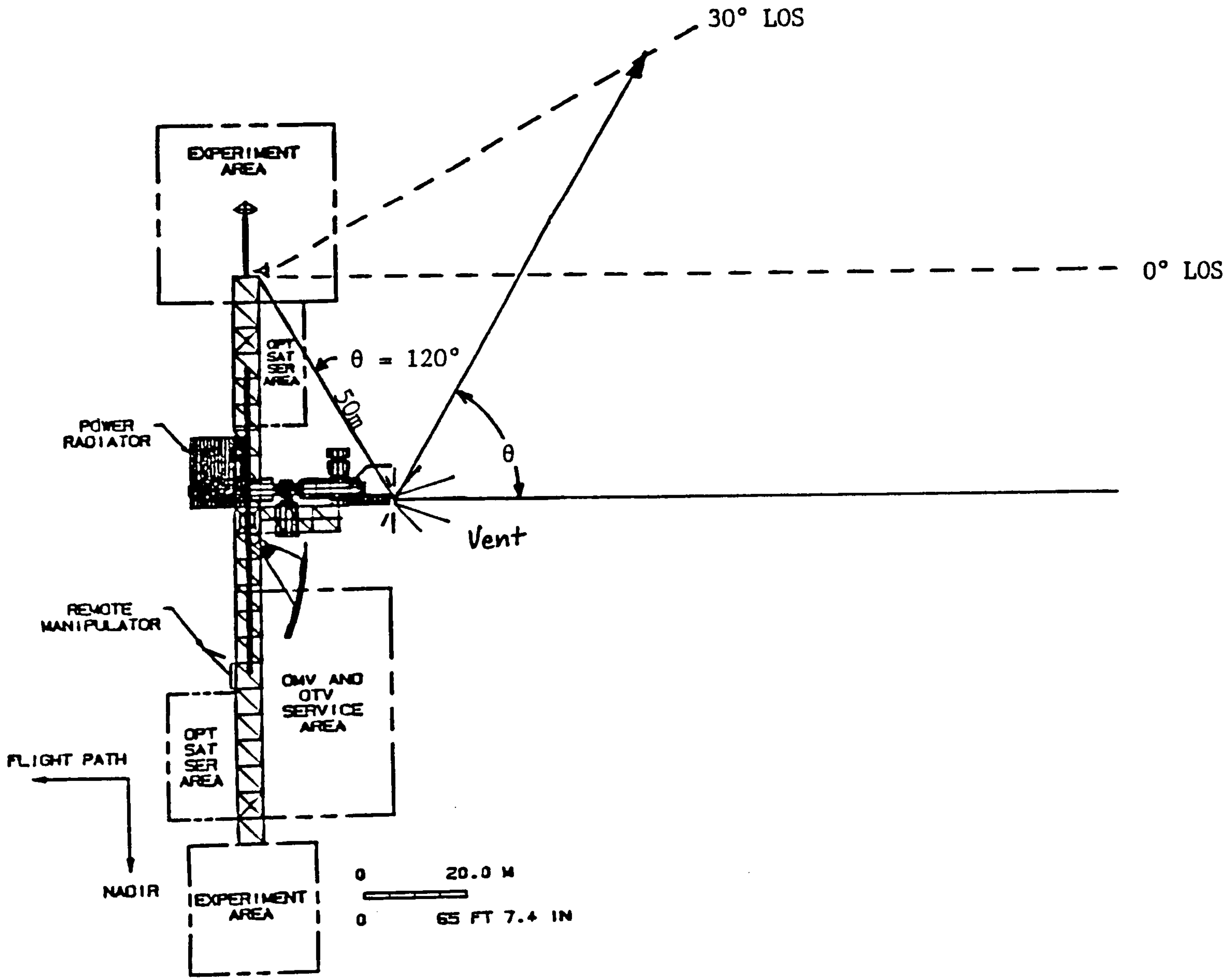
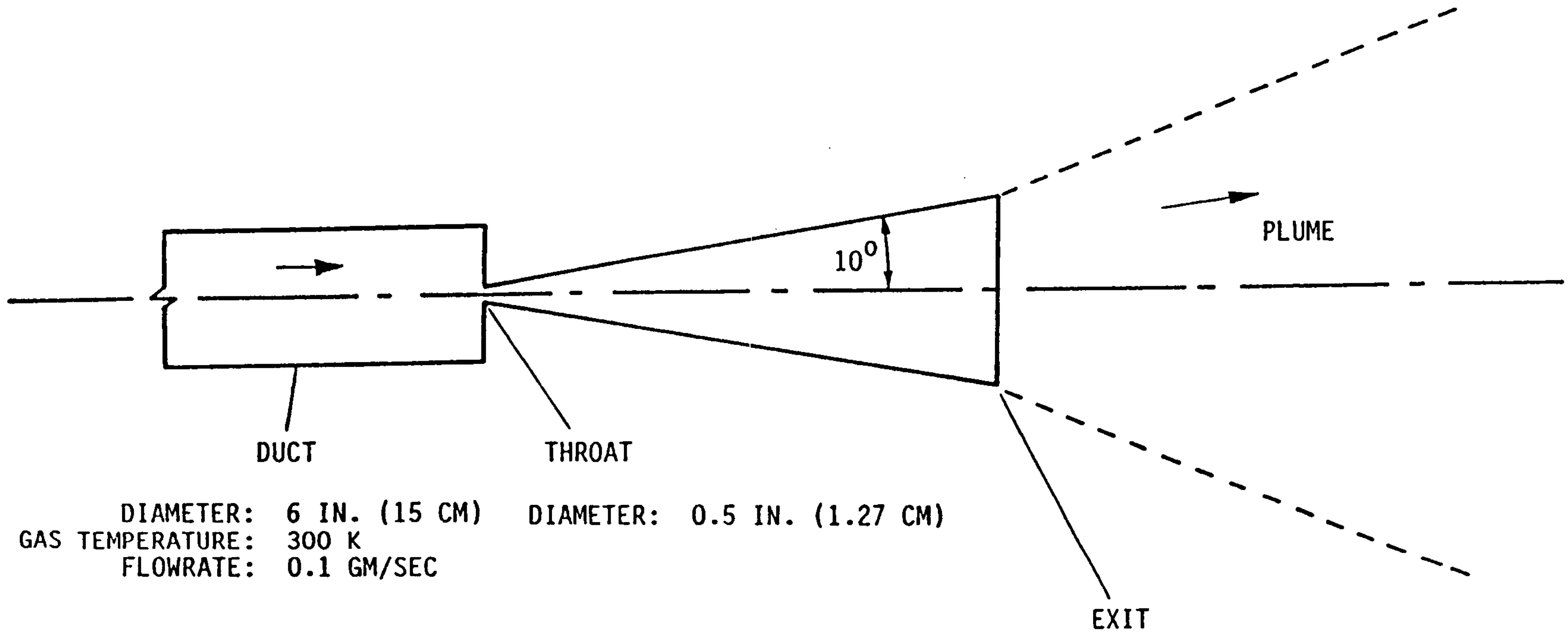


FIGURE 5.1.1. WASTE VENT



DIAMETER: 6 IN. (15 CM)
GAS TEMPERATURE: 300 K
FLOWRATE: 0.1 GM/SEC

DIAMETER: 0.5 IN. (1.27 CM)

DIAMETER: 8 IN. (20.3 CM)
AREA RATIO: 260
MFP: 4 CM
VELOCITY: 2215 FT/SEC (67500 CM/SEC)
TEMPERATURE: 24 K

BASIS FOR DESIGN

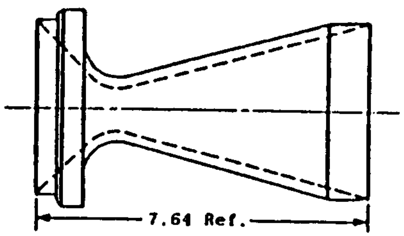
NO BOUNDARY LAYER AT THROAT

PLUME RETAINS SHAPE OF NOZZLE IN FREE MOLECULAR FLOW

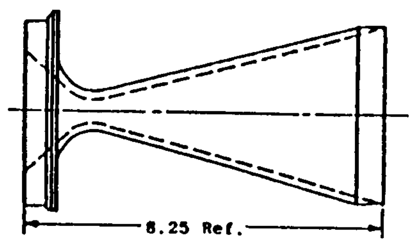
FREE MOLECULAR FLOW WITHIN NOZZLE

FIGURE 5.1.2. JSC VENT DETAILS

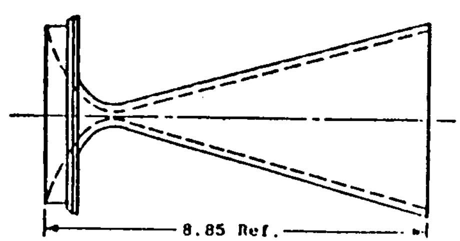
NOZZLE CONFIGURATIONS



a. Throat diameter, 1.0 in.; area ratio, 16; lip thickness ≈ 0.001 in.



b. Throat diameter, 0.6 in.; area ratio, 44.4; lip thickness ≈ 0.001 in.



All Dimensions, In.

Nozzle Half-Angle, 15 deg

c. Throat diameter, 0.2 in.; area ratio, 400; lip thickness ≈ 0.125 in.

TEST MATRIX

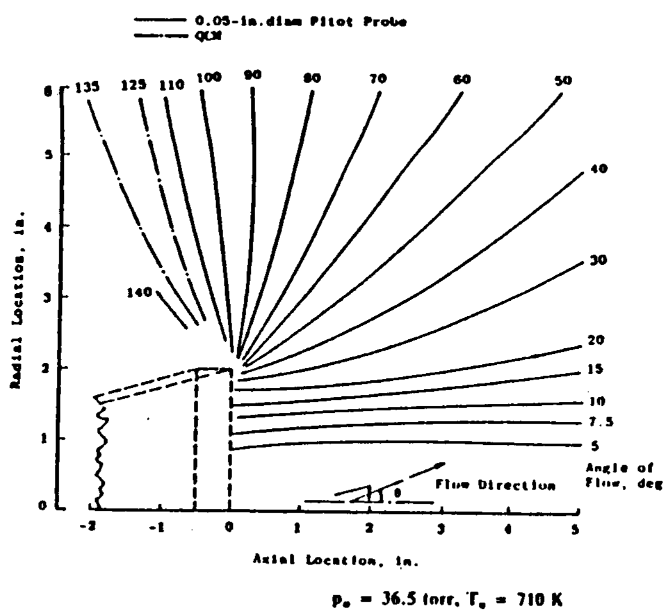
Nozzle / Exit Mach Number	a 4.0	b 5.1	c 8.0	b 5.1	c 8.0
Throat Diam, in. / cm	1.0 / 2.54	0.6 / 1.52	0.2 / 0.51	0.6 / 1.52	0.2 / 0.51
Stagnation Pressure, torr	10.8	36.5	283	24	188
Stagnation Temperature, K	487	710	710	288	300
Thin Lip	X	X		X	X
Thick Lip	X		X		
Varying Background Pressure	X	X	X	X	X
Varying Background Cryopumping	X	X			
Pitot Probe	X	X	X	X	X
Free-Molecule Pressure	X	X			
Free-Molecule Heat Transfer		X			
Electron Beam	X	X			
QCM	X	X			

FIGURE 5.1.3. CARBON DIOXIDE EXPANSION INTO VACUUM (AEDC-TR-85-26)

(AEDC-TR-85-26)

NOZZLE b, AREA RATIO 44.4

CONSTANT FLOW ANGLES



CONSTANT CO_2 NUMBER DENSITIES

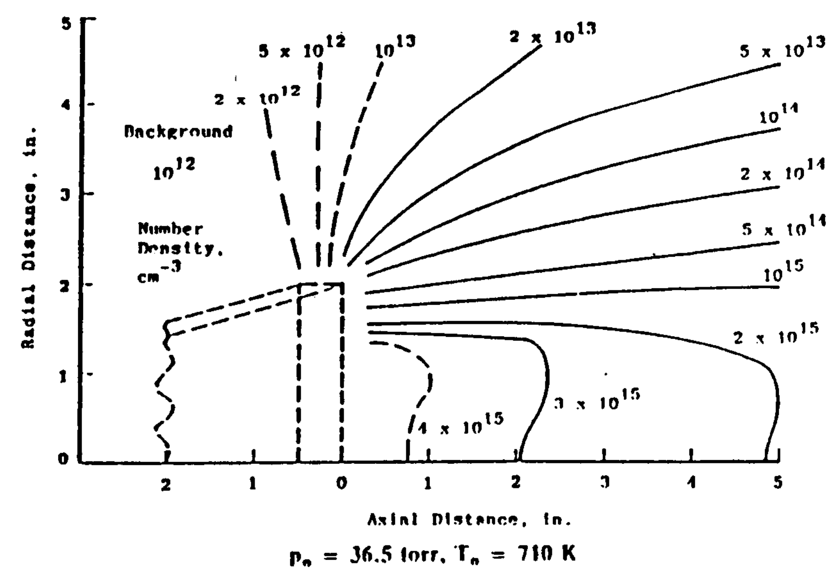


FIGURE 5.1.4. CARBON DIOXIDE EXPANSION INTO VACUUM

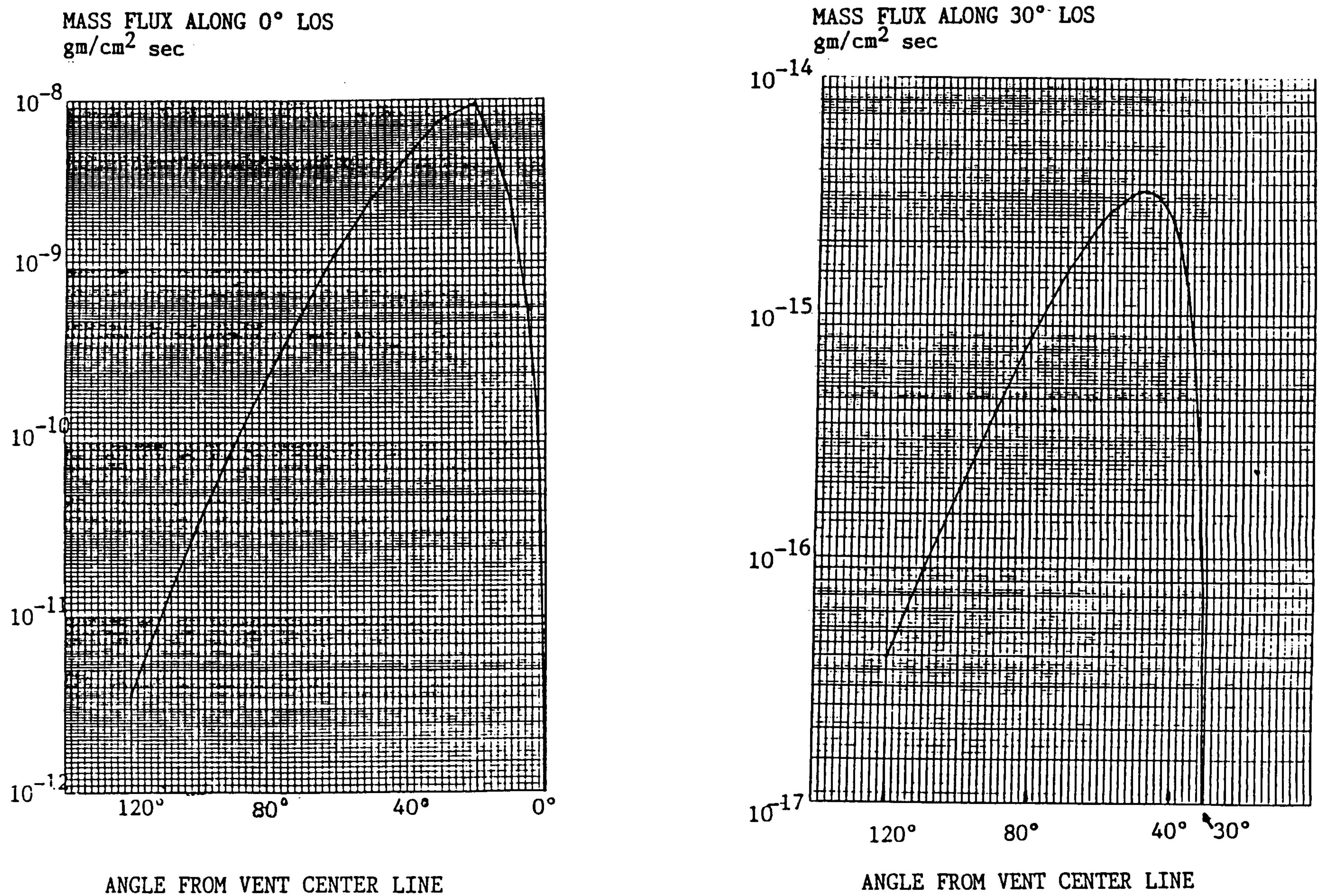


FIGURE 5.1.5. MASS FLUX TO LINE-OF-SIGHT FROM VENT

As a result of our analysis of the JSC vent concept, the following conclusions were drawn.

1.) The JSC vent would produce significant backflow at the payload locations.

2.) Free molecular flow does not exist for duct pressures between 76 torr and 7.6 torr and flow rates between .01 gm/sec and 1 gm/sec (JSC proposed range).

3.) AEDC-TR-85-26 nozzles with throat to exit ratios between 16 and 400, and pressures between 10.8 torr and 188 torr, show significant backflow.

4.) Scaling to the JSC nozzle produces fluxes at payload positions on the order of $2x10^{-13}$ to $2x10^{-12}$ $gm/cm^2/sec$ for flows of 0.1 to 1 gm/sec.

5.1.2 Ram Pressure (Dual Keel Configuration)

The dual keel configuration of Space Station places the instrument payloads a considerable distance from the solar panels. Due to the distance separating the instrument payloads from the solar panels, along with the orientation of the space station relative to Ram, it is considered unlikely that the Ram pressure buildup in front of the solar panels will cause any direct contamination problems for the payloads. However, there is a concern that the density buildup in front of the solar panels might cause sufficiently high number column densities along lines of sight near the panels to create viewing degradation in these regions.

To obtain representative number column densities for lines of sight passing near the solar panels, a 26 by 10 meter rectangle was modeled in a perpendicular orientation relative to Ram. Figures 5.1.6 and 5.1.7 show the isodensity profiles obtained for the solar panel when perpendicular to Ram, with Ram at a density of $5x10^9$ $molecules/cm^3$. Lines of sight originating at the corner of the upper truss, and passing

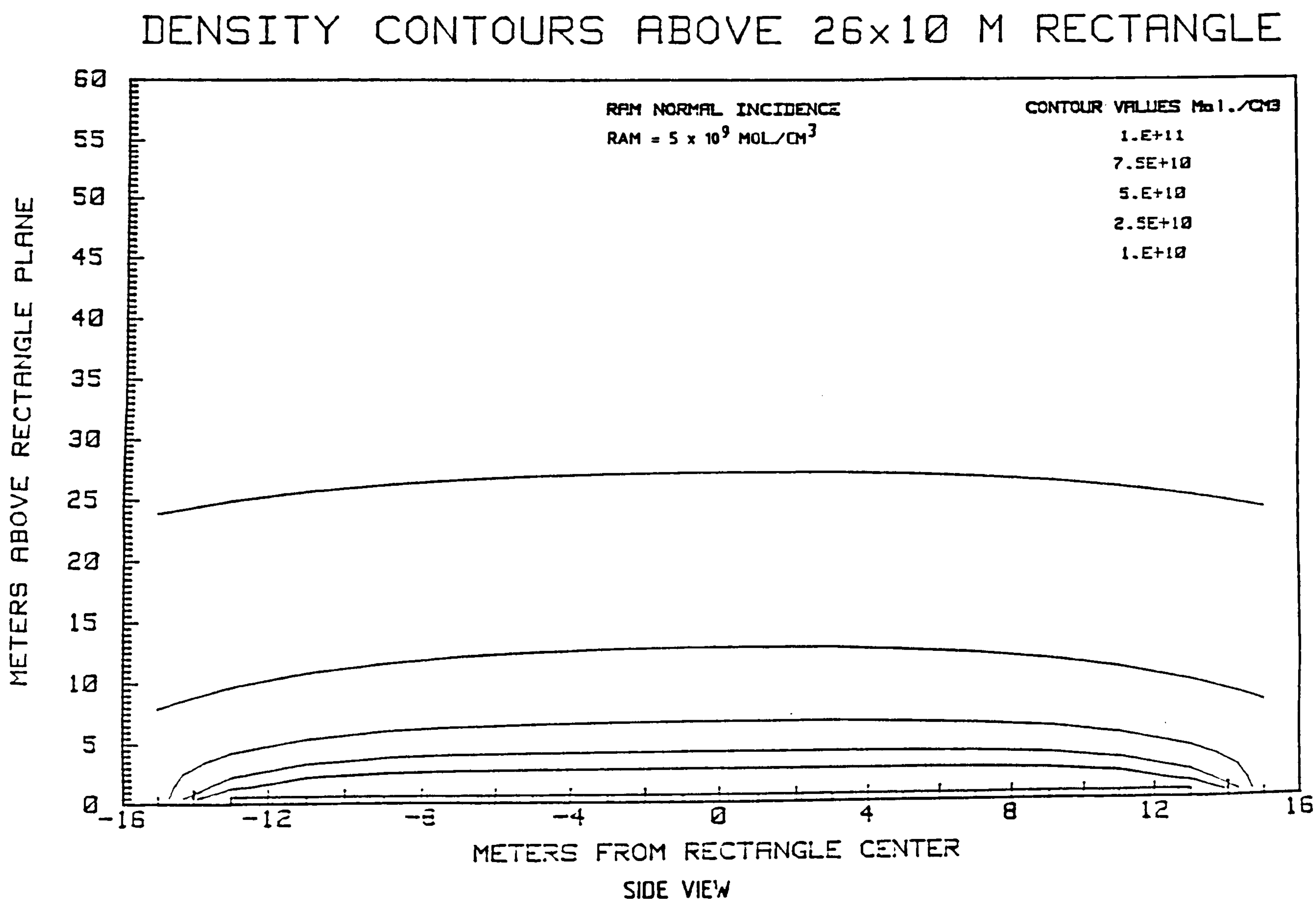


FIGURE 5.1.6. ISODENSITY PLOTS SOLAR ARRAY (SIDE VIEW)

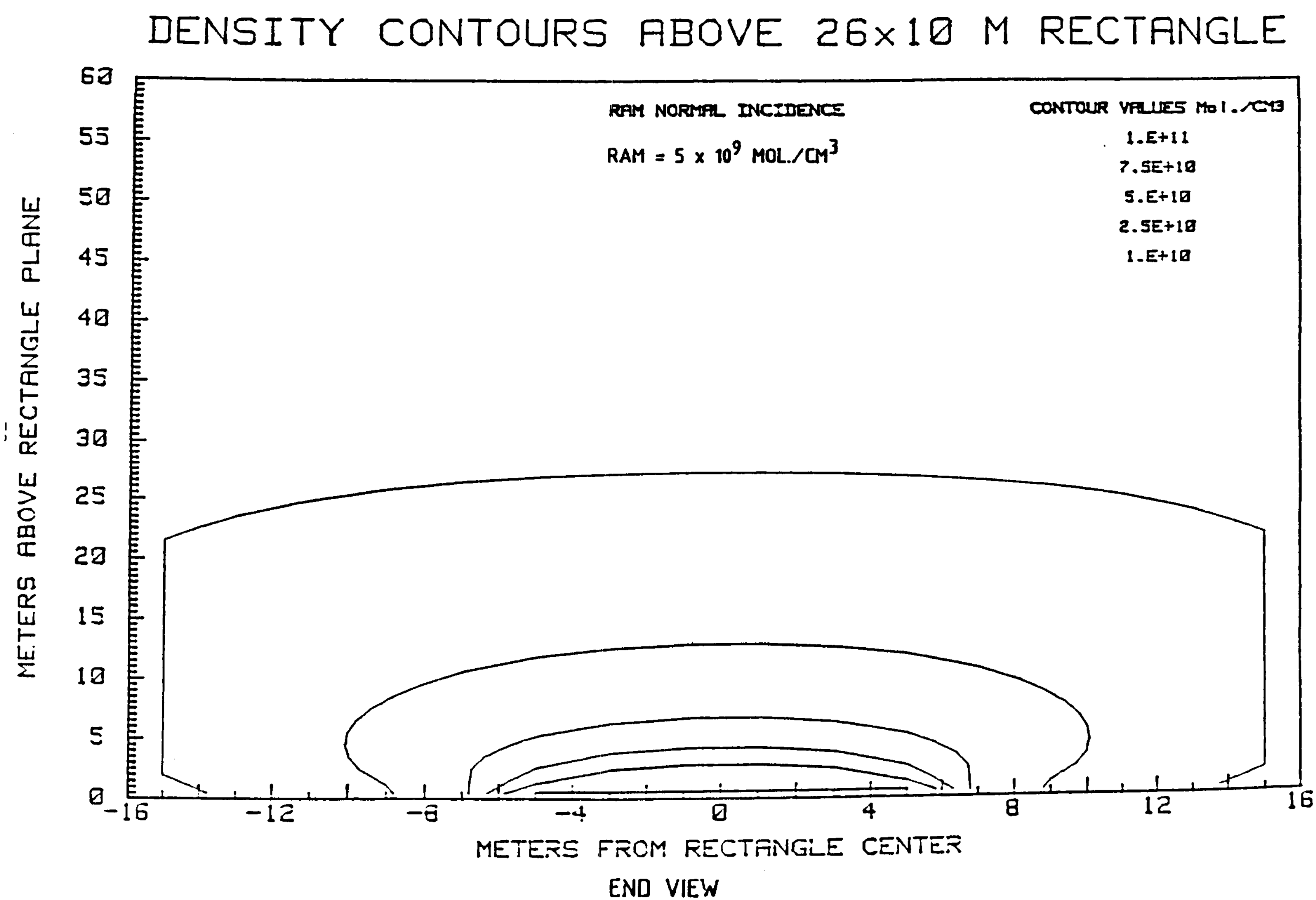


FIGURE 5.1.7. ISODENSITY PLOTS SOLAR ARRAY (END VIEW)

through the enhanced density region above the panel were determined. These lines of sight are depicted in Figure 5.1.8 The molecular number density was integrated along each line of sight to obtain the molecular number column density. The number column densities calculated are listed in Figure 5.1.9

Any structure with large surfaces has the potential to create contamination problems due to Ram pressure buildup. Structural portions of one payload may cause viewing restrictions for another payload due to high number column densities along lines of sight passing through the region near the structure. An example for the dual keel configuration would be the antenna for experiment TDMX 2153 which could cause high number column densities for some lines of sight from other experiment locations on the payload truss. Figure 5.1.10 shows two lines of sight and their corresponding number column densities.

Although a surface oriented normal to the Ram will produce the maximum density buildup, surfaces oriented parallel to the Ram will also cause a density buildup. The density buildup for a parallel surface is due to the thermal component of the ambient which causes a small portion of the ambient molecules to impact the parallel surface and be accommodated and reemitted. A "snowball" effect is started because the reemitted molecules collide with other ambient molecules causing even more surface impacts. The result is a Ram density buildup especially towards the back of the parallel surface. Figure 5.1.11 shows the isodensity profile for a 26 by 10 meter rectangle oriented parallel to the Ram flow.

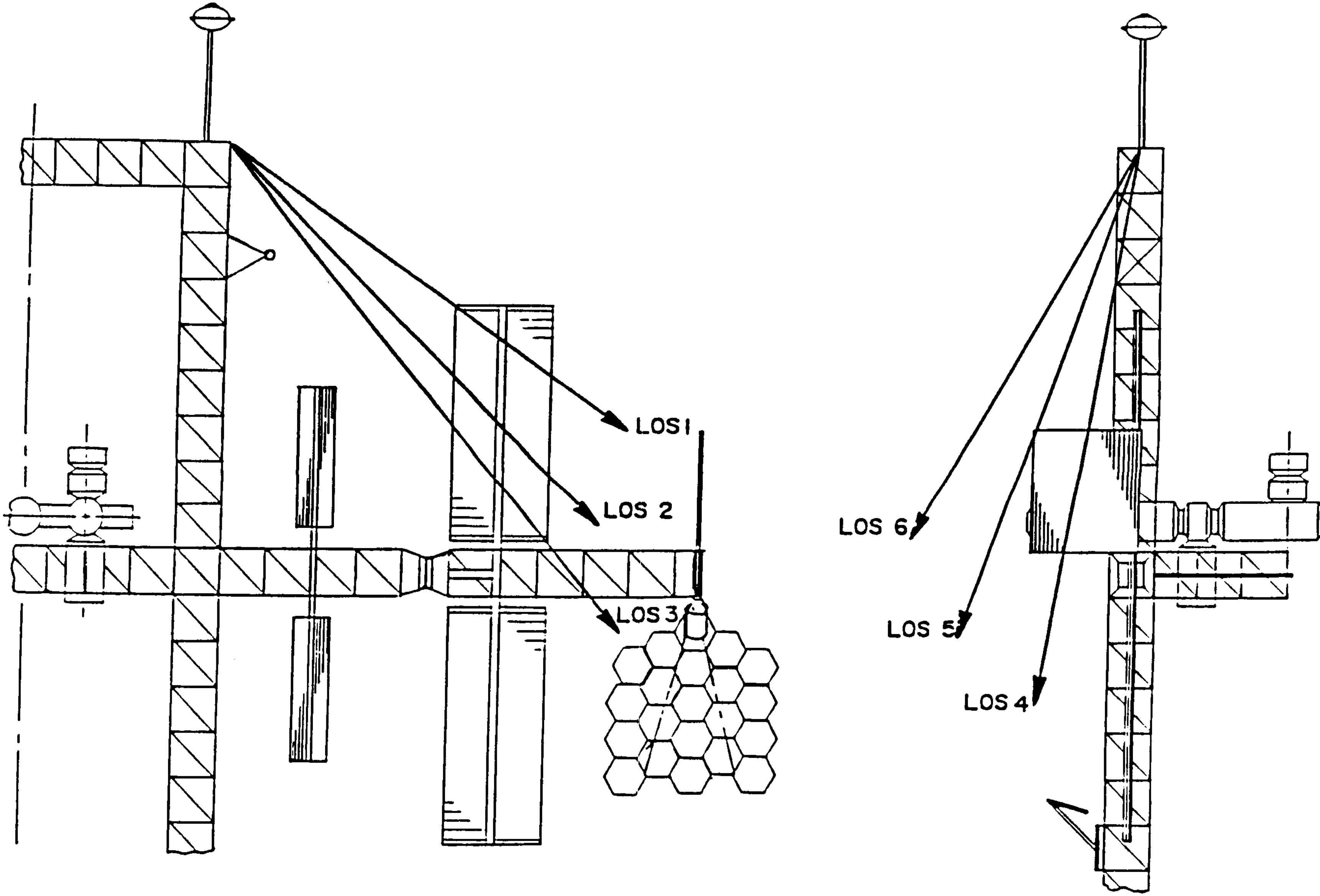


FIGURE 5.1.8. RAM PRESSURE NUMBER COLUMN DENSITIES LINES-OF-SIGHT SOLAR ARRAY

LINE OF SIGHT	NCD
LOS 1	2.60×10^{14} mol./cm^2
LOS 2	3.45×10^{14} mol./cm^2
LOS 3	3.36×10^{14} mol./cm^2
LOS 4,5, & 6 ARE ABOVE LOS 2 AT 10°, 20°, AND 30° RESPECTIVELY	
LOS 4	1.12×10^{14} mol./cm^2
LOS 5	6.64×10^{13} mol./cm^2
LOS 6	4.44×10^{13} mol./cm^2

FIGURE 5.1.9. NUMBER COLUMN DENSITIES FOR LOS ABOVE SOLAR PANEL

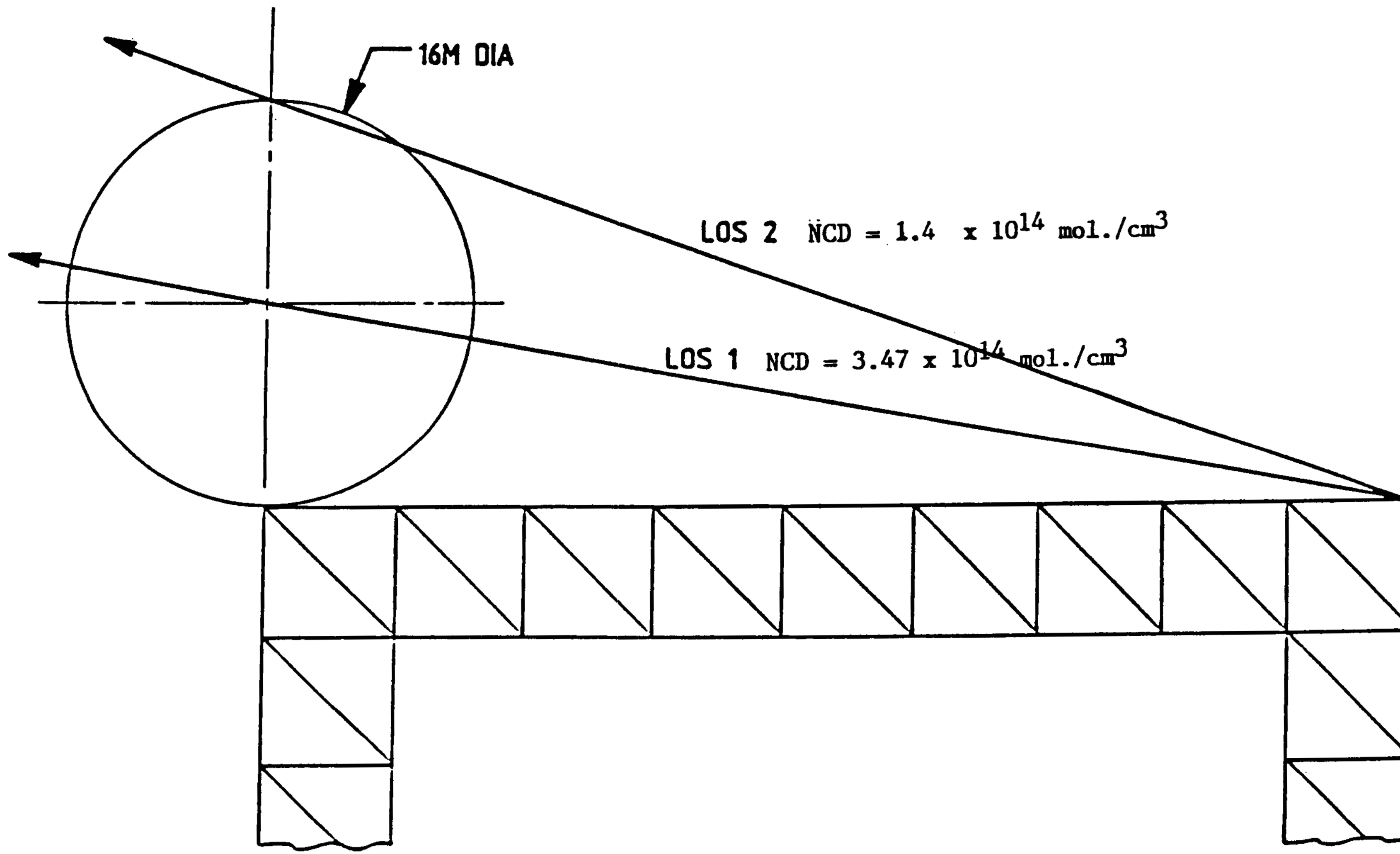


FIGURE 5.1.10. LINES-OF-SIGHT - ANTENNA

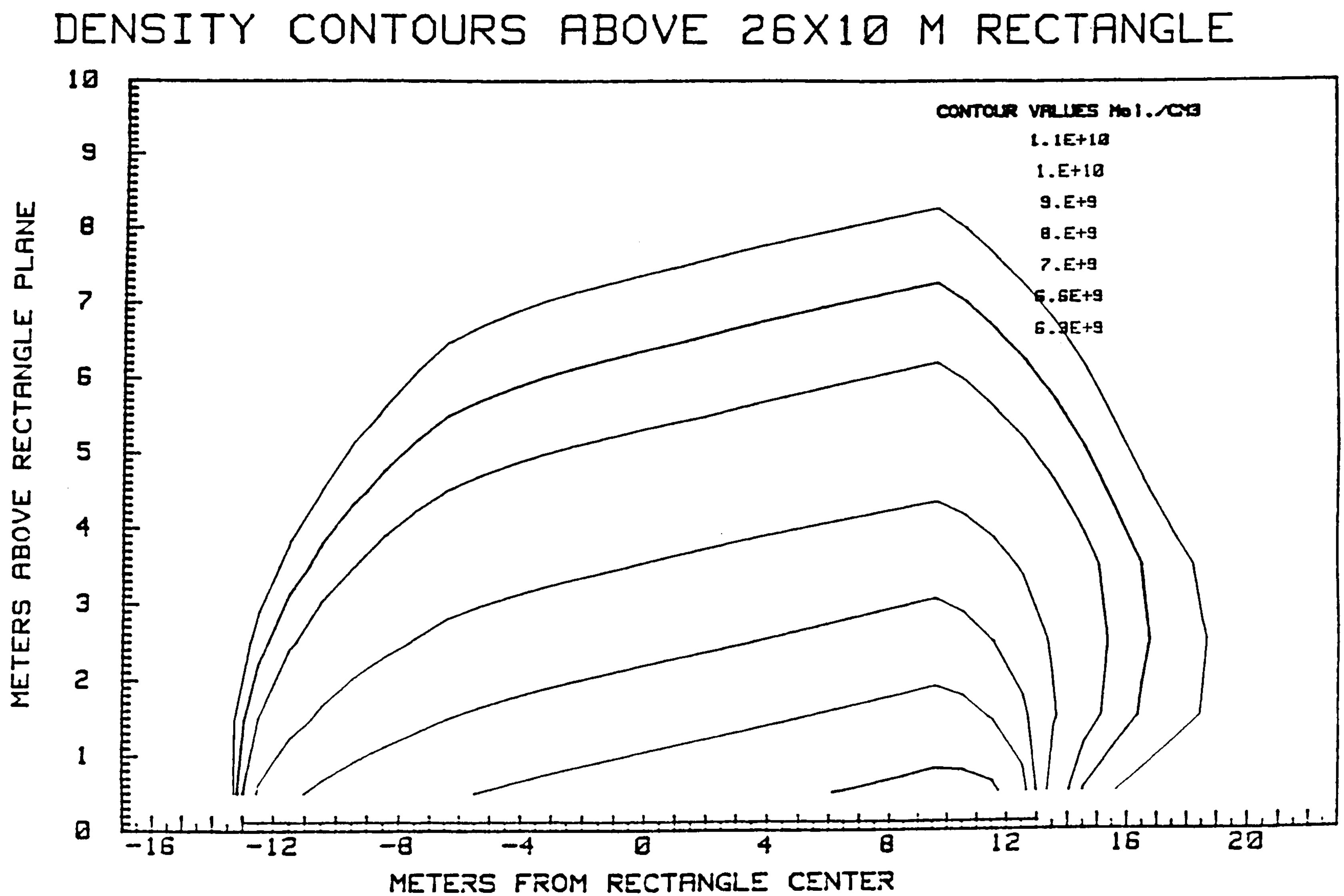


FIGURE 5.1.11. PARALLEL ISODENSITIES, SIDE VIEW

5.1.3 Contamination Control Working Group Inputs and Support

This section presents the recommended additions and changes to the contamination control requirements that became part of the CCWG meeting. The SEA inputs were presented to OSSA CODE E and contamination personnel at Goddard. They were incorporated into a joint CODE E/GSFC position. Not all of these recommended changes were incorporated in the final change request. See Section 4 for the latest requirements as of the date of this report.

5.1.3.1 Molecular Depositions

Stated in JSC CR

The Flux of molecules emanating from the core Space Station must be limited such that: The mass deposition rate of a 300 K surface located both at the PMP and perpendicular to the Z-axis and for solar power system critical surface with an acceptance angle of 2 steradians shall be no more than 1.0 x 10^{-14} gm/cm^{2}sec.

The mass deposition rate on a 300°K surface located at the PMP and perpendicular to the Z-axis with an acceptance angle of 0.1 steradian shall be no more than 1.0 x 10^{-16} gm/cm^{2}sec.

The mass deposition rate on a 5°K surface located at the PMP and perpendicular to the Z-axis with an acceptance angle of 0.1 steradian shall be no more than 2.0 x 10^{13} gm/cm^{2}sec excluding condensation of atmospheric constituents.

Recommended Additions

Deposition levels on U.V. optics shall not exceed 20 Å (related to a 10% reflectivity change for lyman - alpha, 1216Å).

5.1.3.2 Molecular Column Densities

Stated in JSC CR

10^{11} molecules/cm^2 for each of H_2O, CO_2 and all other IR emitting species.

10^{13} molecules/cm^2 for each of O_2, N_2, H_2 and noble gasses or non IR emitters.

Recommended Changes

10^{11} molecules/cm^2 for each of H_2O, CO_2, and 10^{11} molecules for all other IR emitting species combined.

10^{13} molecules/cm^2 for each of O_2, N_2, H_2, and 10^{13} for noble gases or non IR emitting species.

5.1.3.3 IR Background Brightness

Stated in JSC CR

Wavelength (u)	Recommended Spectral (watt m^{-2} $sr^{-1}nm^{-1}$)	Maximum Spectral Irradiance (uniform background) (watt m^{-1} $sr^{-1}nm^{-1}$)
1	1.0×10^{-10}	1.0×10^{-10}
5	7.0×10^{-12}	7.0×10^{-12}
10	1.0×10^{-11}	1.4×10^{-11}
<30	1.0×10^{-10}	4.2×10^{-11}
>30	1.0×10^{-10}	4.2×10^{-9}
300	1.0×10^{-10}	4.2×10^{-8}

Recommended Change

Wavelength (μ)	Recommended Spectral (watt $m^{-2}sr^{-1}nm^{-1}$	Maximum Spectral Irradiance (uniform background) (watt $m^{-2}sr^{-1}nm^{-1}$)
1	1.0×10^{-10}	1.0×10^{-10}
5	5.0×10^{-11}	1.0×10^{-10}
10	4.0×10^{-11}	2.0×10^{-10}
≤ 30	1.0×10^{-11}	4.0×10^{-11}
>30	6.0×10^{-12}	3.0×10^{-11}
300	3.0×10^{-12}	1.0×10^{-11}

5.1.3.4 Particulate Background and Deposition

Stated in JSC CR

Release of particles from core Space Station shall be limited to one particle 5 microns or larger per orbit per 1x 10^{-5} steradian field of view as seen by a 1 meter diameter aperature telescope. Requirement is applicable to all regions.

Recommended Additions

Particulates in the field-or-view of U.V. payloads shall be less than or equivalent to a class 10,000 clean room over a distance of 100 meters.

Particulate deposition on external payload optics shall not exceed a surface area obscuration of more than 3%, evaluated at 6400Å.

Particulate deposition on sun shades shall not change (degrade) the BDRF of that surface more than 1 percent at 6400Å.

5.1.3.5 Servicing

Stated in JSC CR

Particulate deposition rates of TBD gm/cm^{2}sec and molecular deposition rates of 1 x 10^{-13} gm/cm^{2}sec as measured on a 300° K surface with an acceptance angle of 2 steradian. These requirements also are referred to in paragraph 2.1.2.4.3.2. of JSC 30000.

Recommended

The service bay shall be capable of maintaining a surface during its exposure period in the service bay to a class 400 surface as defined by Mil. Std. 1246A. Molecular deposition rates of 1 x 10^{-13} gm/cm^{2}sec as measured on a 300°K surface with an acceptance angle of 2π steradian.

5.1.3.6 Venting

The venting issue was previously discussed in section 5.1.1 of this report.

Essentially, the JSC position was to define a region 2 that violated the 10^{13} column density requirement.

SEA proposed no such definition since it was configuration dependent and the vent nozzle flowfield was not accurately defined. The SEA position was that venting should be allowed if it meets the column density requirements. If not, a waiver should be required or no venting allowed.

5.1.4 Presentations/Meetings

Several meetings were held on venting issues with NASA, OSSA, Dr. Lubert Leger, NASA, JSC, Dr. Ray Gause NASA, MSFC and telecons with Al Bailey, AEDC. The meetings of importance were:

- NASA Headquarters, 11 August 1986, on requirements and venting issues in review and preperation for the contamination Control

Working Group Meeting at JSC.

- o CCWG, JSC, 13-14 August 86. This working meeting updated the requirements in JSC 30000 for contamination control. At this meeting an agreed upon revised set of requirements was arrived at by all attendees. This included personnel from GSFC, MSFC, JSC, LeRC, OSSA CODE E, JPL, NRC CANADA, NASDA JAPAN, ESA, Science and Engineering Associates, Martin Marietta and McDonnell Douglass Major improvements in the requirements were achieved at this meeting.

5.2 CONSTANT ALTITUDE VERSUS CONSTANT DENSITY

During the course of the study SEA was asked to see what contamination issues existed, if any, if the Space Station were to fly at a constant ambient atmosphere density instead of a constant altitude. The constant density corresponds to solar max at 250 NM. Instead of having periods of less ambient density the Space Station would change altitude to keep it constant.

The following is a summary of the constant density impact.

In general the relative changes compared to constant altitude were not severe.

- o Ram pressure buildup on windward facing surfaces would be higher than the average at constant altitude.
- o Atomic oxygen erosion rate will increase
- o Return flux of contaminants could increase slightly
- o Glow phenomena would be slightly higher in intensity
- o RCS engine useage may be different

5.3 ALTERNATE REPHASED SPACE STATION INCREMENT 2 (TRANSVERSE BOOM)

On September 8, 1986 SEA was requested to quickly assess the impact of the transverse boom configuration on contamination as compared to dual keel. On 12 September 1986 the quick look analysis was zap mailed to OSSA headquarters. Several presentations resulted after this initial mailing.

5.3.1 General Assessment

Generally the transverse boom is worse than the dual keel from a contamination point-of-view. Table 5.3.1 shows the comparison. It should not be construed the problems are insurmountable rather just greater in a relative sense.

The preliminary results of this quick look study is shown in Table 5.3.2.

Table 5.3.1-Contamination Differences Between Dual Keel and Transverse Boom.

- o DUAL KEEL
  - Generally acceptable for most payloads
  - Small portions of viewing directions may be unacceptable
  - Uncontrollable sources (leakage, vents,ram pressure) are at long distance from payloads - dilutes impact
  - Top edge of solar panels (Z Position) less than payload Z position
- o TRANSVERSE BOOM
  - Major Contamination sources and payloads are much closer to each other
  - Solar panels and radiators obstruct viewing
  - Leakage near payloads

- RCS near payloads
- Return flux of outgassed materials to payload surfaces greater
- Background glow much more available to be within field-of-view or intercept field-of-view
- Spatially and temporally more variable
- Shuttle is closer to payloads during manuevers
- Ionized specie concentration potential is greater - affects some payloads detrimentally while neutrals do not

Table 5.3.2 - Preliminary Results of Transverse Boom Trade

- o Leakage from pressurized modules approaches column density requirements limit for a significant portion of payload viewing direction
- o Solar panels, concentrators and radiators along boom cause significant Ram pressure buildup-eliminates a large volume of payload viewing by exceeding column density requirements
- o Venting adds to column densities, payload/vent relative location reduces amount of venting that is allowable
- o Return flux/deposition potential greater because of solar panel/module outgassing and relative locations
- o Leakage at 5 lbs/day approaches 10^{11} mol/cm^2 for H_2O, CO_2, at locations along boom (out to 15 meters from center) looking along Z and areas aft
  - Impacts most phase 1A experiments
  - Opinion is leakage flow rate of 5 lbs/day for all pressurized modules is not reasonable (too low)
  - Skylab spec was 14.7 lb/day and actually showed near 7.5lbs.

- Shuttle spec is at 6.5 lbs/day
- Feel that greater than 5 lbs/day per module is closer to reality - especially as seals deteriorate

o Ram pressure on solar panels shows that viewing between 30 and 60 degrees off of Z towards X and 30 to 70 degrees off of X towards Y (into the ram direction) exceeds acceptable column densities

o Venting at 5 lbs/day exceeds column density requirements for lines-of-sight looking aft at 60-70 degrees off of Z axis

o Further analysis required
- Updates of the above
- RCS (Resistojets)
- Shuttle Rendezvous
- Wake Region Densities
- Surface and Far Field Glow Potential
- Leakage rate assessment (major impact)

5.3.2 Leakage as a Contaminant Source

The alternate rephased space station configuration places the instrument payloads in close proximity to the habitation modules (see Fig. 5.3.1). Consequently, concern exists with regards to the leakage from the habitation modules as a source of contamination. In efforts to obtain order of magnitude values, a first look model was developed. The modules were simulated using a rectangle with an area approximately equal to the projected area of the modules. Based on a leakage rate of 5 lbs./day for the entire habitation volume, a pseudo surface emission rate for one side of the rectangle was given a rate of 1.08×10^{14} molecules/cm^2/sec. This rate assumes an average molecular weight of 28gm/mole for the escaping gas The velocity of the escaping molecules was calculated to be 3.16×10^4

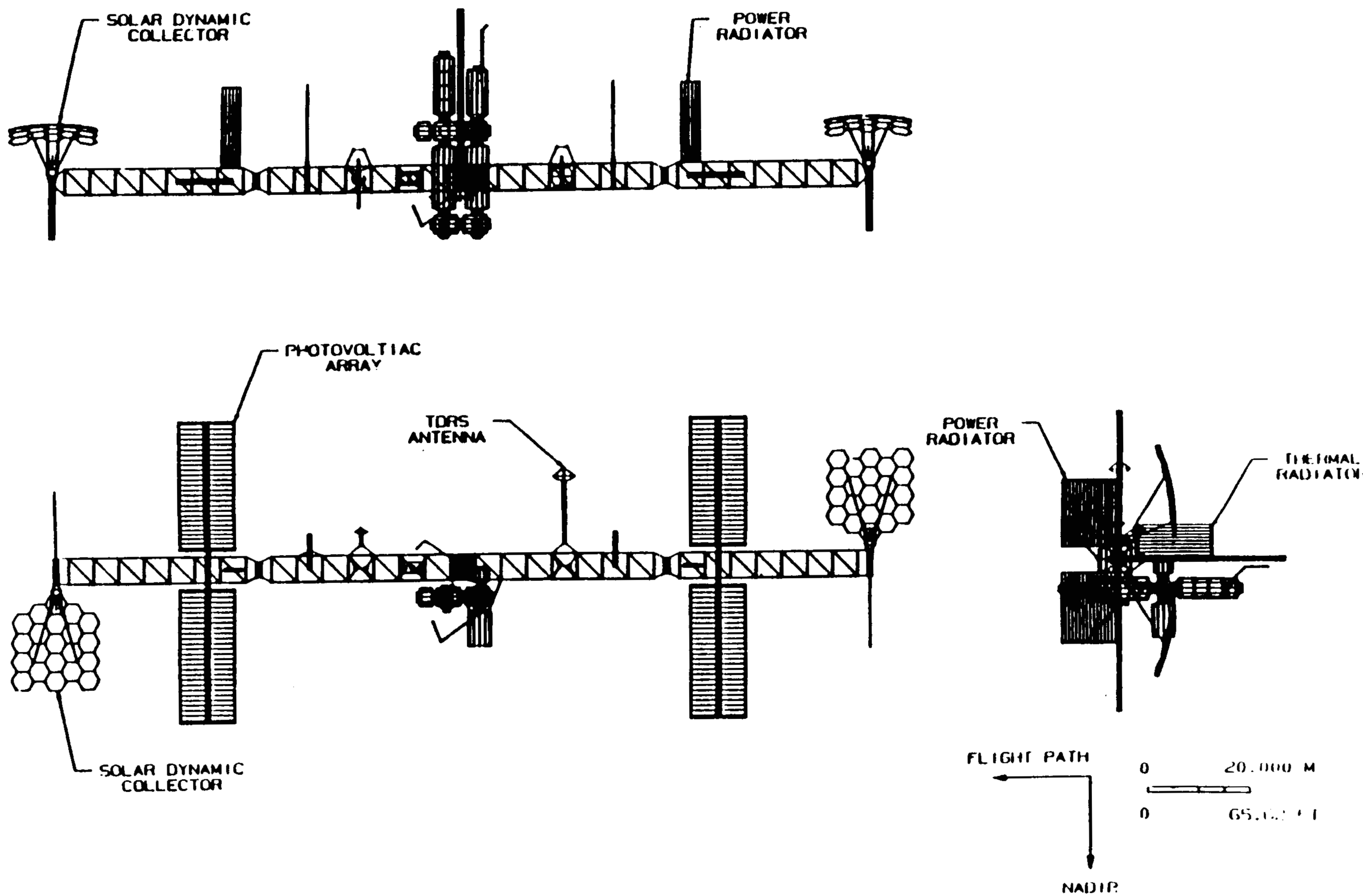


FIGURE 5.3.1. SPACE STATION - TRANSVERSE BOOM CONFIGURATION

cm/sec at its effective aperture. This calculation was based on a cabin temperature of 293°K at 1 atmosphere and an average ratio of specific heat for the escaping gas of 1.35. The molecular number density due to leakage was calculated to a matrix of volumes above the simulated modules. Numerous lines-of-sight orginating from points along the truss were determined. Density integrations were computed along each line-of-sight to obtain corresponding number column densities. Figures 5.3.2 and 5.3.3 show the origin and direction for 28 lines-of-sight. Figures 5.3.4 and 5.3.5 show the calculated number column density corresponding to each line-of-sight. Also shown are the calculated number column densities based on a more realistic leakage rate of 5 lbs./module/day.

5.3.3 Venting Analysis

Another contamination source which required modeling was the habitation module waste vent. The vent was placed at the end of the habitation modules furthest from the truss corresponding to a distance of about 20 meters from the truss centerline. This geometry was modeled as shown in Fig. 5.3.6. Molecular number densities were calculated for a matrix of volumes in the vent plume. Lines-of-sight from two origin points were determined as shown in Figures 5.3.7 and 5.3.8. Both line-of-sight origins represent points along the truss where instruments could be located. Integration of the density along each line-of-sight was performed to compute the corresponding number column density. The computed number column densities are shown in Figure 5.3.7, 5.3.8 and 5.3.9.

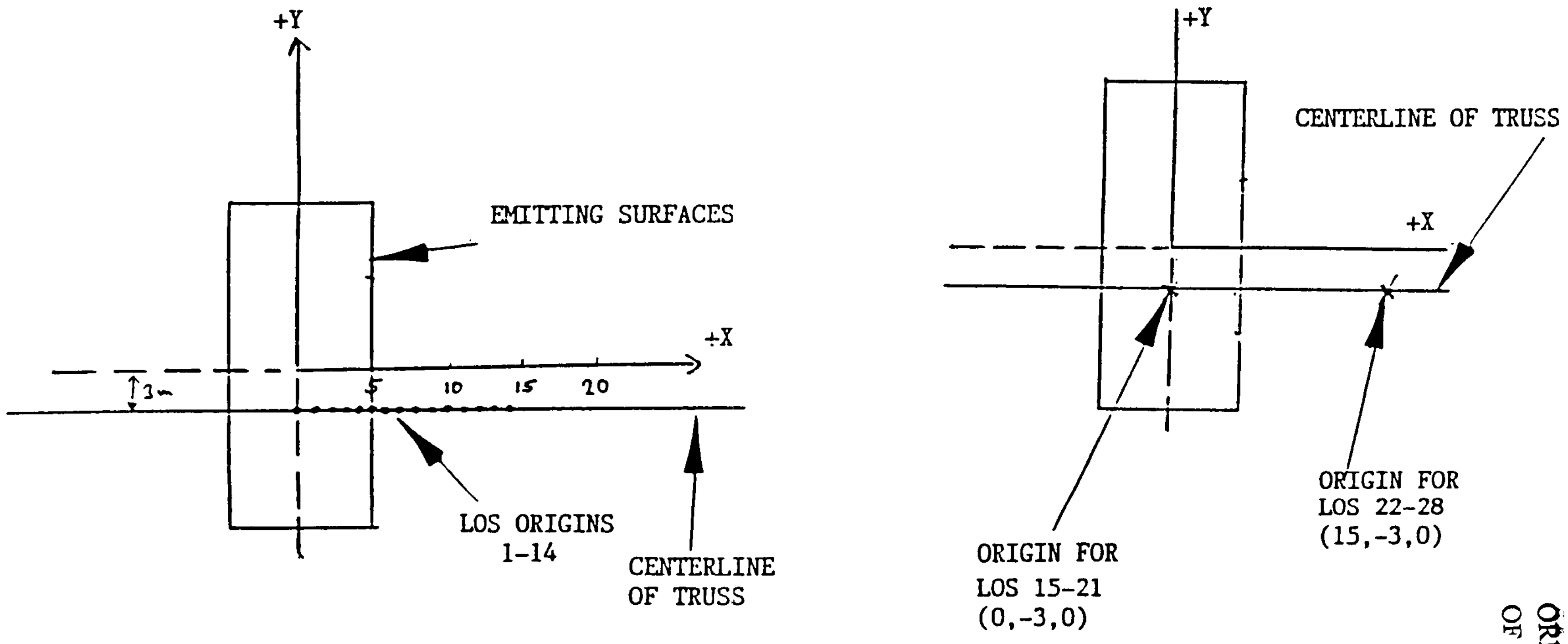


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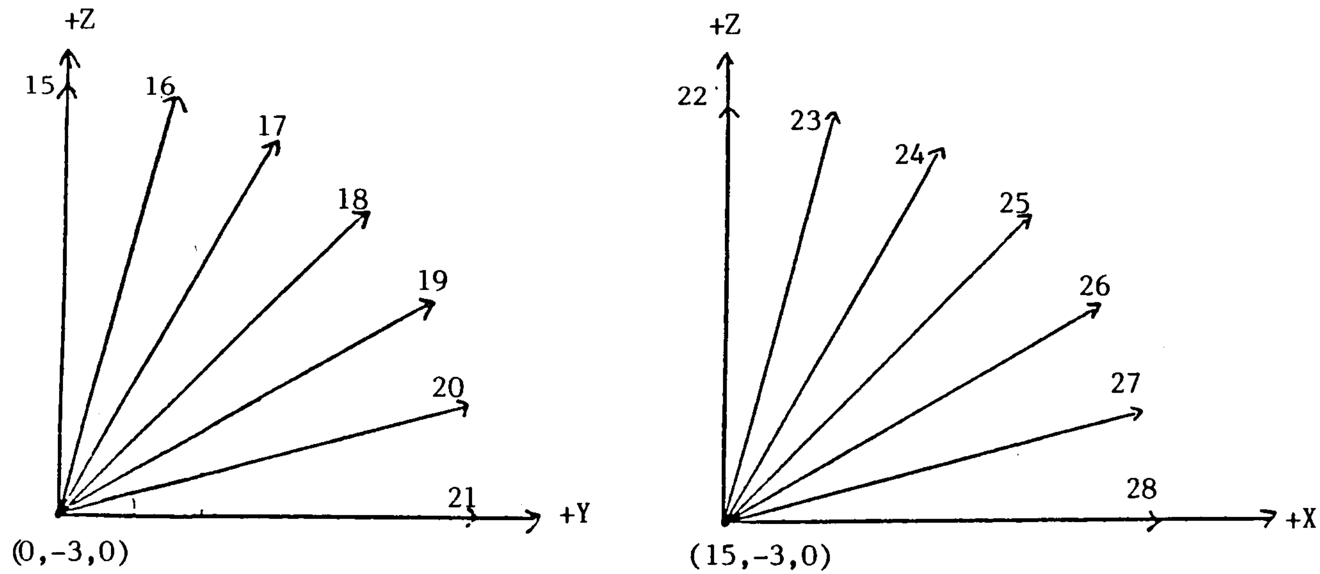
FIGURE 5.3.2. LEAK SIMULATION REPHASED SPACE STATION



LEAKAGE CONSTITUENTS:

H_2O - 2%

N_2 - 75%

CO_2 - 2%

O_2 - 21%

FIGURE 5.3.3. LINES-OF-SIGHT FOR ORIGIN AT 15 METERS FROM CENTER

Direction vectors for LOS 1-14 are all in the +Z direction (0 , 0, 1)

LOS #	NCD (5 lbs./day)	NCD (5 lbs./module/day) (30 lbs. total)
0	5×10^{12} mol./cm^2	3×10^{13} mol./cm^2
1	5×10^{12}	3×10^{13}
2	4.8×10^{12}	2.9×10^{13}
3	4.6×10^{12}	2.8×10^{13}
4	4.2×10^{12}	2.5×10^{13}
5	3.7×10^{12}	2.2×10^{13}
6	3.1×10^{12}	1.9×10^{13}
7	2.5×10^{12}	1.5×10^{13}
8	2.2×10^{12}	1.3×10^{13}
9	1.9×10^{12}	1.1×10^{13}
10	1.7×10^{12}	1.0×10^{13}
11	1.5×10^{12}	9.0×10^{12}
12	1.4×10^{12}	8.4×10^{12}
13	1.2×10^{12}	7.2×10^{12}
14	1.1×10^{12}	6.2×10^{12}

FIGURE 5.3.4. LEAKAGE RESULTS

C-2

LOS #	ANGLE TO +Z	NCD (5 lbs./day)	NCD (5 lbs./module/day) (30 lbs. total)
15	0	5×10^{12} mol./cm^2	3×10^{13} mol./cm^2
16	15	5.2×10^{12}	3.1×10^{13}
17	30	5.6×10^{12}	3.4×10^{13}
18	45	5.9×10^{12}	3.5×10^{13}
19	60	6.1×10^{12}	3.6×10^{13}
20	75	7.8×10^{12}	4.7×10^{13}
21	90	1.8×10^{13}	1.1×10^{14}
22	0	1.1×10^{12}	6.7×10^{12}
23	15	1.4×10^{12}	8.4×10^{12}
24	30	2.0×10^{12} -	1.2×10^{13}
25	45	2.9×10^{12}	1.8×10^{13}
26	60	3.9×12^{12}	2.3×10^{13}
27	75	5.3×10^{12}	3.2×10^{13}
28	90	6.6×10^{12}	4.0×10^{13}

FIGURE 5.3.5. LEAKAGE SIMULATION

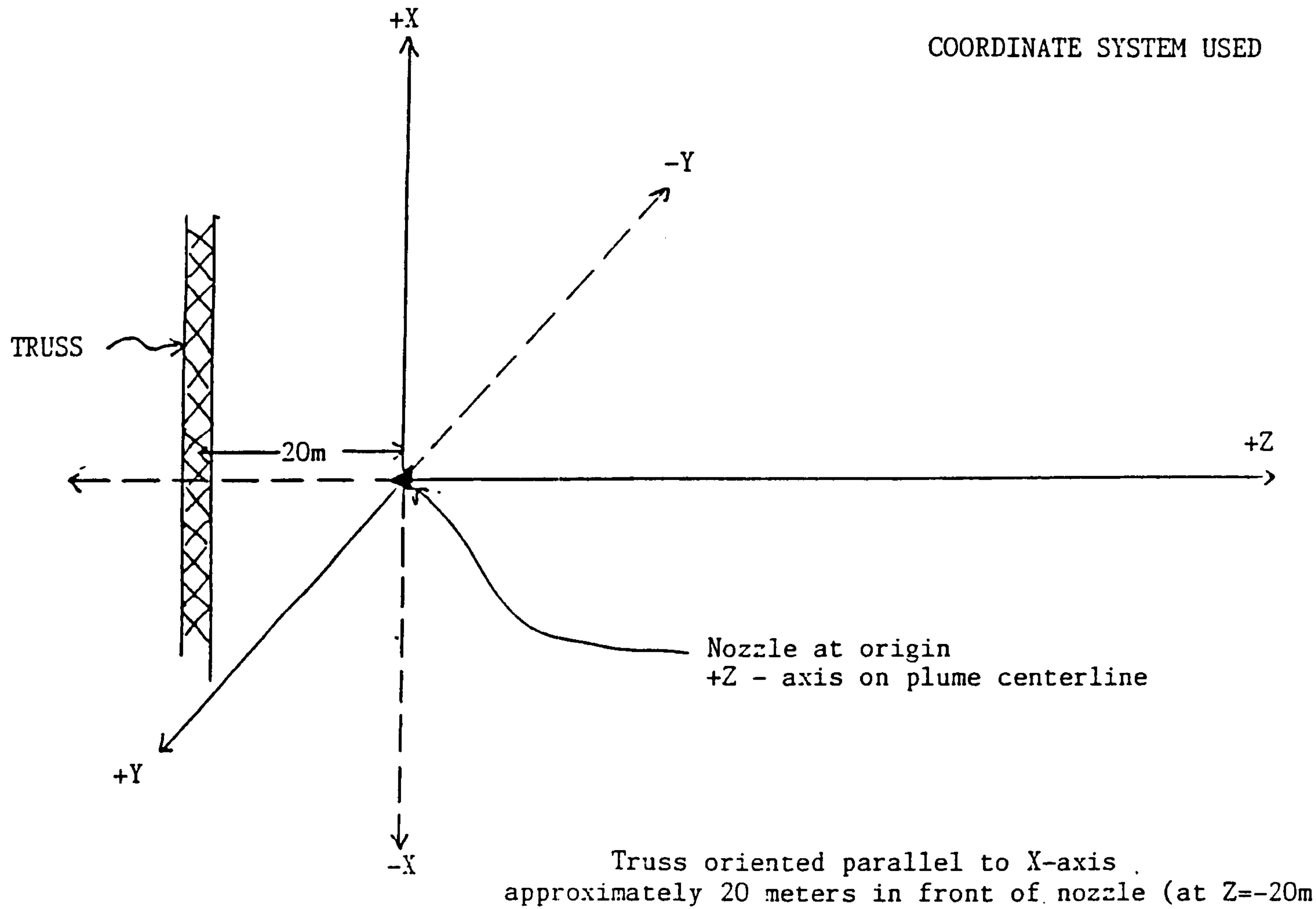
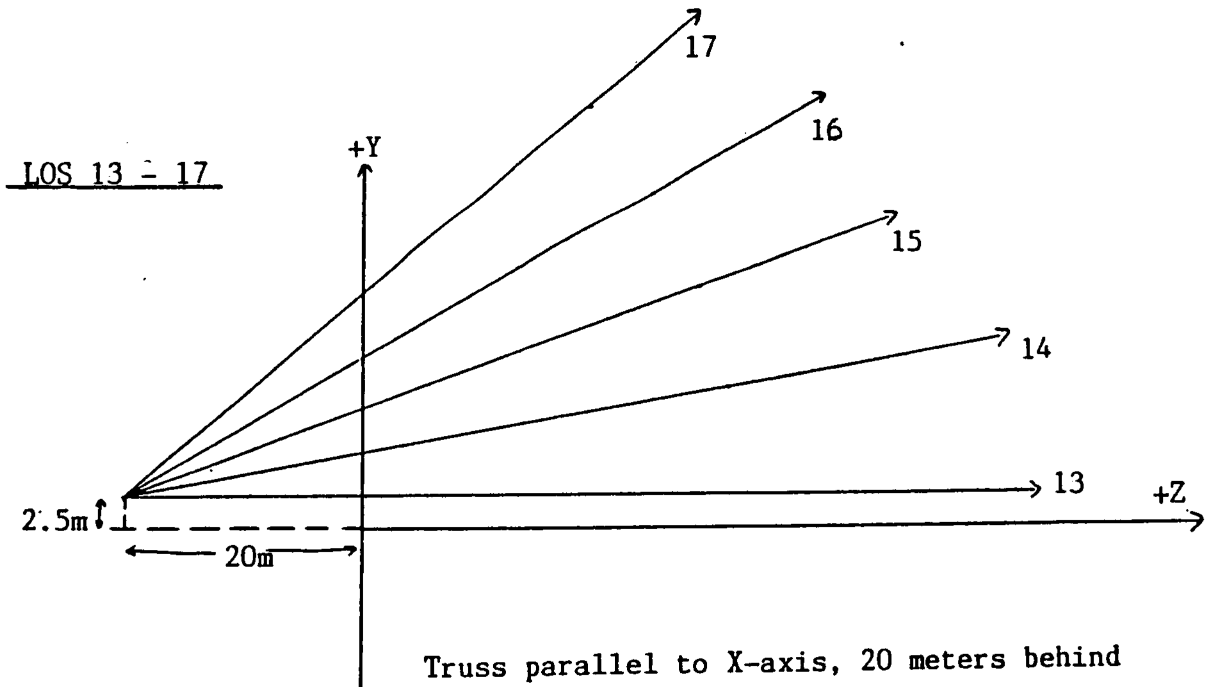


FIGURE 5.3.6. VENT PLUME ORIENTATION



Truss parallel to X-axis, 20 meters behind X-Y plane.

FLOW RATE

= 5 lbs/day
= .026 GM/S

ANGLE	LOS#	NCD (molecules/cm^2)
0	13	2.2×10^{13}
10	14	1.0×10^{13}
20	15	1.7×10^{12}
30	16	2.1×10^{11}
40	17	2.3×10^{10}

FIGURE 5.3.7. VENT COLUMN DENSITIES, REPHASED SPACE STATION

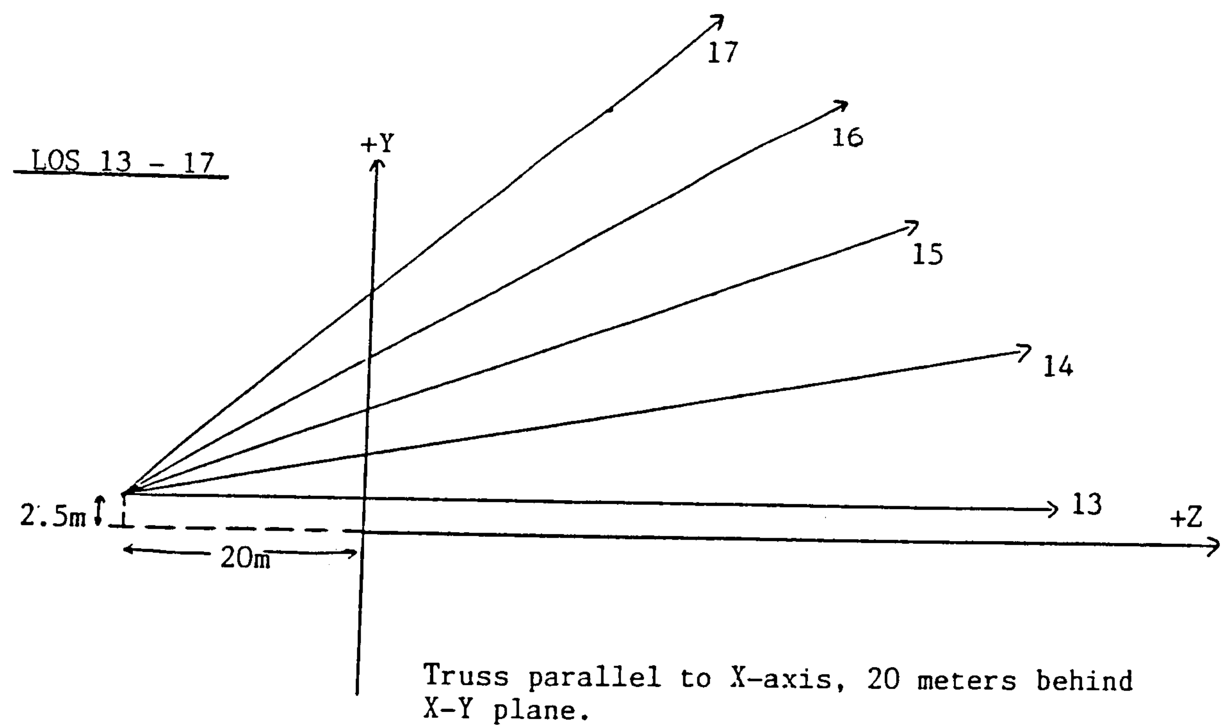
LOS 5-8 above LOS 1 in the plane formed by LOS 1 and the line parallel to Y passing through the origin for LOS 1.

Angle to LOS 1	LOS #	NCD (molecules/cm^2)
10^o	5	1.13×10^{12}
20^o	6	2.02×10^{11}
30^o	7	5.32×10^{10}
40^o	8	7×10^{9}

LOS 9-12 above LOS 4 in the plane formed by LOS 4 and the line parallel to Y passing through the origin for LOS 4.

Angle to LOS 4	LOS #	NCD (molecules/cm^2)
10^o	9	4.16×10^{12}
20^o	10	1.16×10^{12}
30^o	11	1.42×10^{11}
40^o	12	1.7×10^{10}

FIGURE 5.3.8. VENT COLUMN DENSITIES, REPHASED SPACE STATION



FLOW RATE

= 5lbs/day
= .026 GM/S

ANGLE	LOS#	NCD (molecules/cm^2)
0	13	2.2×10^{13}
10	14	1.0×10^{13}
20	15	1.7×10^{12}
30	16	2.1×10^{11}
40	17	2.3×10^{10}

FIGURE 5.3.9. VENT COLUMN DENSITIES

5.3.4 Ram Pressure on Reconfigured Solar Panels

The alternate rephased space station configuration places the payload instruments much closer to the solar panels than in the dual keel configuration. Figure 5.3.10 shows geometric orientation of the solar panels relative to the truss on which the payload instruments will be mounted. The Ram density buildup above the solar panel was calculated assuming a Ram direction vector normal to the plane of the solar panel. Lines-of-sight were determined for several representative instrument locations on the truss as depicted in Figure 5.3.10. The integrated number column densities were computed for the lines-of-sight and are listed in Figure 5.3.11. It can be seen from the results that there may be rather large regions in an instruments field-of-view which are unusable due to excessive number column densities from Ram density buildup.

5.3.5 Presentations/Meetings

For the rephased space station action items/trades two meetings were most important.

- o NASA Headquarters, 17 Sept 86, on transverse boom versus dual keel impact on contamination. Attendees from NASA/MATSCO were:

  Richard Sade

  John Hilchey

  Aronld Nicogossian

  Mike Davarian

  Gary Musgrave

  Larry Chambers

- o NASA Headquarters, 22 September 1986, on transverse boom versus dual keel impact on contamination. Atendees from NASA/MATSCO were:

  Dick Halpern

Mike Davarian

Sam Keller

Gary Musgrave

David Black

Fritz Von Bun

Ray Gause

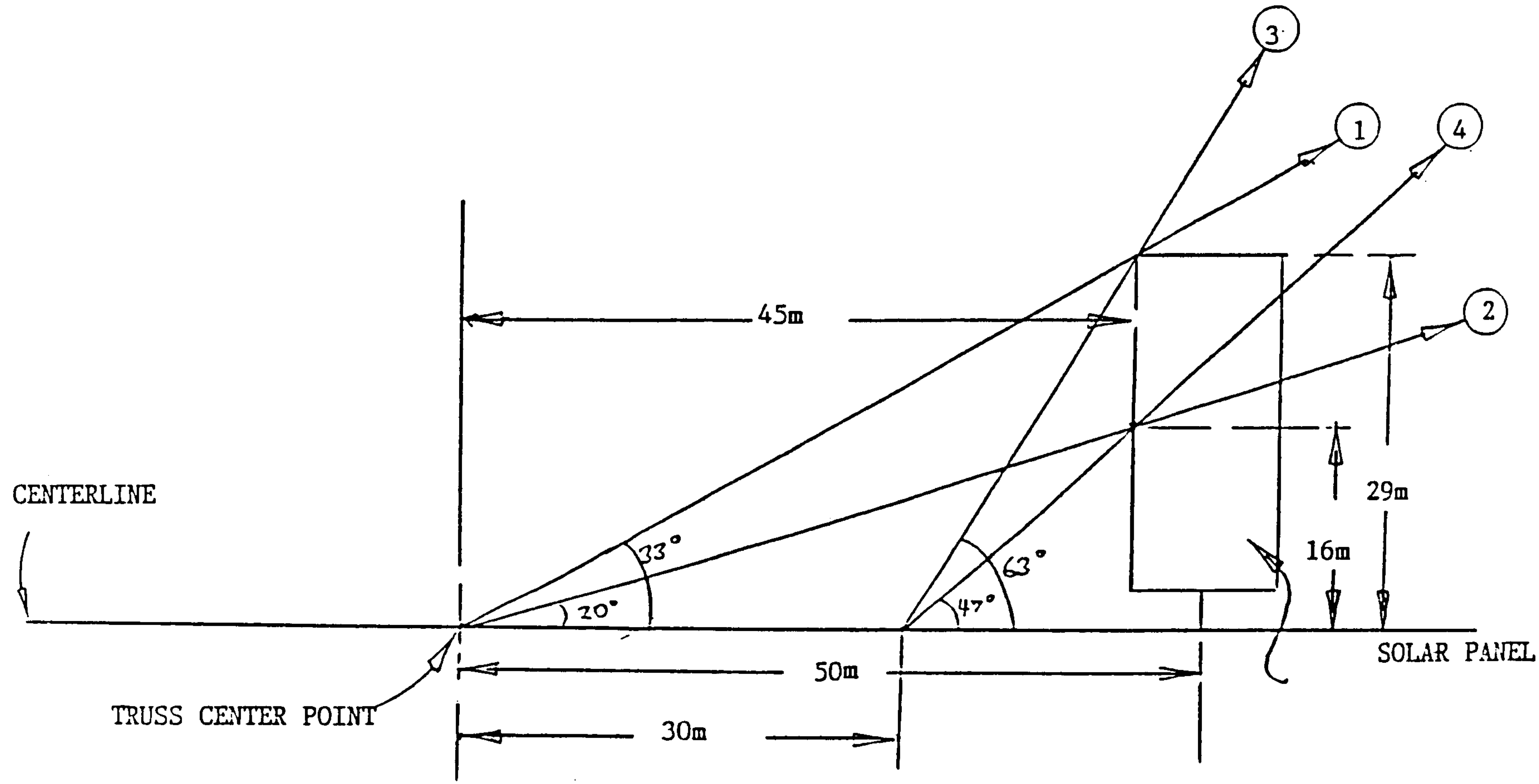
Lubert Leger

Horst Ehlers

Ed Reeves

Mark Sistilli

Larry Chambers



LOS 5 & 6 above LOS 2 at 15° and 30° respectively (out of solar panel plane)

LOS 7,8,9,10 above LOS 4 at 15°,30°,45°,60°,75° respectively (out of solar panel plane)

FIGURE 5.3.10. RAM PRESSURE BUILDUP - SOLAR PANEL REPHASED SPACE STATION

LOS #	ANGLE TO SOLAR PANEL PLANE	NCD DUE TO AMBIENT BUILDUP
1	0°	4.5×10^{13} mol./cm^2
2	0	2.1×10^{14}
3	0	5.3×10^{13}
4	0	2.7×10^{14}
5	15	7.3×10^{13}
6	30	2.5×10^{13}
7	15	1.2×10^{14}
8	30	7.8×10^{13}
9	45	4.6×10^{13}
10	60	2.3×10^{13}
11	75	4.5×10^{12}

FIGURE 5.3.11. RAM PRESSURE - SOLAR PANEL

6.0 CONTAMINATION GUIDELINES FOR SPACE STATION PAYLOADS

This section is intended to aid designers and scientists in avoiding pitfalls that may lead to contamination problems during the design, testing, assembly, storage and transportation of a payload. A large part of the information was derived from Dr. Ray Gause, NASA, MSFC who has had a great deal of first hand experience with payload/experiment contamination problems and abatement procedures.

6.1 DESIGN

The experiment design should be performed with the idea in mind that final cleanup or sealing can be made at any stage of assembly in case a contamination problem occurs. Disassemble capability at any stage is a desirable feature for required cleaning. Also the design should consider the lifetime, space platform specifics, and the induced atmosphere of the payload and the platform which is the source of contaminants.

If EVA servicing or retrieval is required the design needs to allow required protection during on site servicing and retrieval. For servicing in the service bay or pressurized clean room, the payload components that are refurbished must be capable of being cleaned in these environments or handled in a manner which does not allow contamination to occur.

If the subassembly testing and integration is completed utilizing the guidelines below, the chance of a serious contamination problem can be minimized.

6.2 MATERIALS SELECTION

The materials used for an experiment are primarily selected for their optical properties or thermal control capability. At the same time the outgassing of these materials must be considered, especially when they have a direct view to critical optical/detector components. The resistance or exposure to the atomic oxygen that is present at low earth orbit is another consideration.

Resistance to impacts by man made orbital debris should also be considered. Approximately 400 particles per meter^2 per year are predicted to impact windward facing surfaces. The particles range from 0.01 to 0.5 mm diameter and will have high relative velocities.

6.2.1 Mass Loss Characteristics

One of the common screening tests for material contamination behavior is the VCM/TML tests. This test procedure holds the sample at 125°C for 24 hours and measures the total mass loss (TML) and volatile condensable material(VCM) that collects on a 25°C surface.

It is possible that even though a material has very low TML or VCM it can still be a problem if it has a line-of-sight to critical optics. It is recommended for this case that optical witness samples are placed in the VCM/TML test and then measured for reflectance or transmission changes after the test. Experience has shown that even though the VCM measured is well below acceptable levels (<0.1%) that witness samples show significant degradation at 1216Å (i.e. 60-90% degradation).

If a material that shows degradation of the optics is still required because of its unique properties, it should be baked out in a thermal vacuum chamber until it reaches acceptable levels.

6.2.2 Atomic Oxygen Effects

The exposure to atomic oxygen of susceptible materials has two major impacts. First the material may be reduced in thickness so that it does not perform its function (i.e. mirror coatings) or secondly, its optical/thermal properties are modified.

The data from flight tests shows that diffuse surfaces become more diffuse and specular surfaces become diffuse. Most of this data was taken during 40 hour exposure periods to varying integrated fluxes of atomic oxygen. Long term exposure could be worse and can be estimated by determining the total fluence to which the surfaces will be exposed.

Flight data also shows that surfaces not exposed to direct flux of atomic oxygen can degrade by received surface scattered flux of ambient atmosphere.

The degradation and/or mass loss of non metallics is discussed in section 2.7 and 2.8 for atomic oxygen.

6.3 ASSEMBLY/BUILDUP PROCESS

This section discusses the multitude of considerations that must be made for assembly of the experiment hardware and associated handling and testing. This process control can be maintained during the buildup or achieved by cleaning later. The choice will be a function of the design and experiment type and sensitivity.

6.3.1. Surface Cleanliness As A Function Of Time And Air Cleanliness

6.3.1.1 Introduction

In the field of contamination control there are two primary documents which are used as reference for cleanliness definition. The first document is the Federal Standard No. 209B which defines the requirements for clean room and work station controlled environments. In particular, Fed. Std. No. 209B provides standardization of definitions and air cleanliness classes for clean rooms and clean work stations. The second document is the Military Standard 1246A which provides a standardized definition for surface cleanliness levels. The problem with these two documents is that each is a stand alone document, and while they do not contradict each other, neither provides any basis or relationship for determining surface cleanliness as a function of air cleanliness class or vice versa. From the practical stand point of a contamination control engineer, the relationship between air cleanliness classes and surface cleanliness levels is very important. This relationship would allow the engineer to predict surface cleanliness levels by knowing the air cleanliness class and time that a particular surface was exposed to that cleanliness class.

6.3.1.2 Air Cleanliness Classes

Federal Standard no. 209B defines air cleanliness in terms of the number of particles greater than 0.5 microns in diameter in one cubic foot. Consequently, an air cleanliness class of 100 would imply 100 particles >0.5 microns per cubic foot. Although any air cleanliness class could be defined in this manner, only three classes are generally used, namely classes 100, 10000, and 100000. The particle size distribution can be approximately described by:

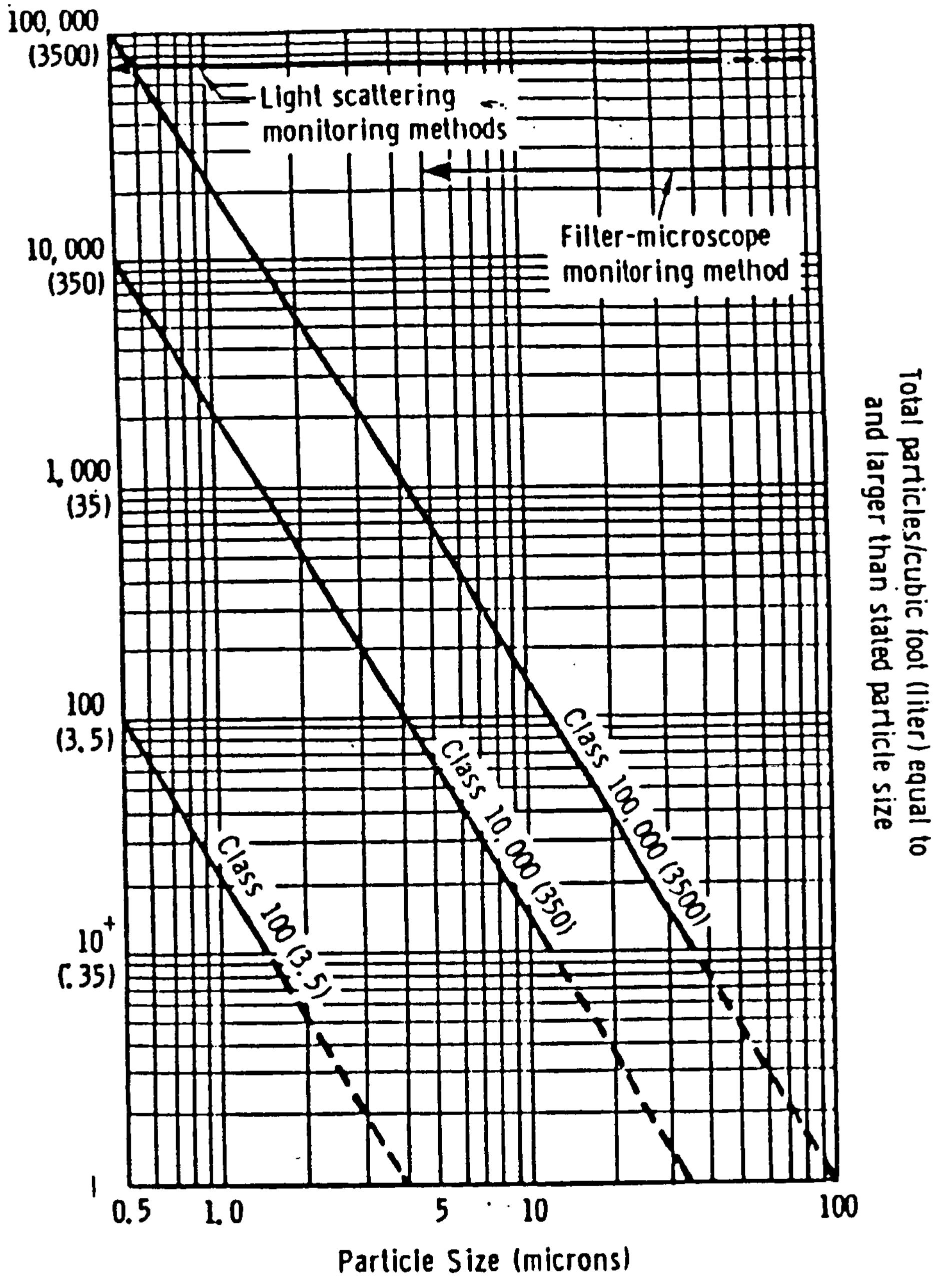
$$\log n = 2.173 \log D - 0.654 + x_c \qquad \text{Eq. 1}$$

where,

$n =$ Number of particles/ft^3 with diameters $>D =$ Diameters of particles in microns

$X_c =$ Clean room air cleanliness level (class)

Figure 6.1 is taken from Fed. Std. 209B and shows graphically the particle distributions for classes 100, 1000, 100000.



+Counts below 10 (0.35) particles per cubic foot (liter) are unreliable except when a large number of samplings is taken.

FIGURE 6.1 PARTICLE SIZE DISTRIBUTION CURVES.

6.3.1.3 Surface Cleanliness Levels

Military Standard 1246A defines surface cleanliness in terms of the largest particle in a particle distribution which is defined by the equation.

$$\log n = 0.9260\ (\log^2 X_1 - \log^2 X) \qquad \text{Eq. 2}$$

where,

n = Number of particles per square foot

X = Particle size in microns

X_1 = Cleanliness level

Figure 6.2 is taken from Mil-Std-1246A and shows graphically the surface particle distributions for surface cleanliness levels 10 through 2000. As an example, a surface cleanliness level of 500 would indicate a particle distribution as depicted by the 500 line in Figure 6.2 with only one particle of 500 microns in diameter, but as many as 5,564,000 particles greater than 1 micron and less than 500 microns per square foot.

6.3.1.4 Fallout Rates

Otto Hamberg[3] had derived a fallout rate equation based on the compilation of many sources of data. The equation is as follows:

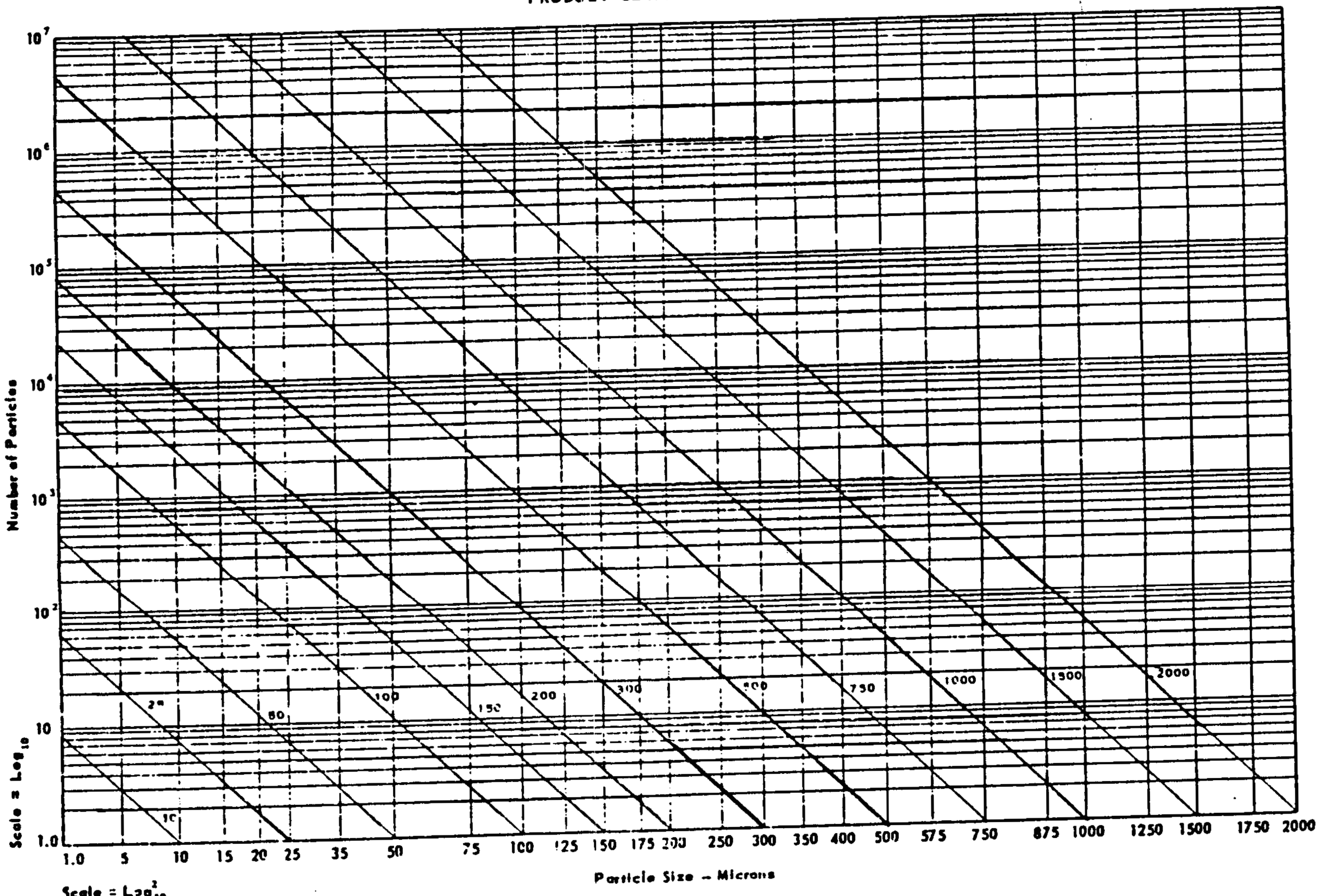
$$n = (2.851 \times 10^3 \times N_c^{\ 0.773}) \qquad \text{Eq. 3}$$

where,

n = Fallout rate, number of particles >5 microns settled/ ft^2/24 hr.

N_c = Air cleanliness, number of particles >5 microns/ft^3 of air. Notice that the fallout rate is a function of air cleanliness as defined in Fed. Std. 209B. The rate equation is based on average

PRODUCT CLEANLINESS LEVELS



Research shows that naturally occurring particulate contamination follows a log-normal distribution with a geometric mean of near one (1) micron particle. This distribution follows a straight line when plotted on a log x $\log^2$ scale graph. The grid is derived from the log-normal Gaussian distribution function which provides a close fit to real contamination data. The lines on the chart represent the maximum contamination permitted for each level and the plot point is the number of particles above given size versus particle size. The curves can be expressed as $\log n = 0.9260 (\mathrm{Log}^2 X_1 - \mathrm{Log}^2 X)$, where n is the number of particles, 0.9260 is the tangent of the angle, X is the particle size, and X_1 is the cleanliness level.

FIGURE 6.2. SURFACE CLEANLINESS LEVELS

cleanrooms with 15 to 20 changes per hour. Cleanrooms with air exchange rates either less than or greater than those stated above require the calculated fallout rates to be adjusted.

6.3.1.5 Cleanliness Level as a Function oF Cleanroom Class and Time

By simple comparison of equations 1 and 2, it becomes obvious that the particle distribution used by Fed. Std. 209B for air volumes is much different than the particle distribution used by Mil-Std-1246A for surface areas. Assuming both distributions are correct for their respective locals (i.e., air volume vs. surface), it is possible to calculate surface cleanliness levels as a function of time and cleanroom class. Equation 1 can be solved for the number of particles n with D = 5 microns. This operation yields:

$$n = 10^{(-2.173 + \log X_c)} \qquad \text{Eq. 4}$$

where,

n = Number of airborne particles >5 microns

X_c = Cleanroom class per Fed. Std. 209B

The value n in equation 4 can now be substituted for N_c in equation 3 to obtain a fallout rate $n. = (2.851 \times 10^3) \times N_c^{\ 0.773}$ Eq. 5

where,

$N_c = 10^{(-2.173 \times \log X_c)}$ (particles)

n = Fallout rate (particles/ft^2/24 hr.)

Equation 2 can be solved for the cleanliness level, X_1 yielding:

$$X_1 = 10 \qquad \text{Eq. 6}$$

where,

N_s = Number of particles

X = Particle size in microns

X_1 = Cleanliness level

For particles sizes greater than 5 microns, and for $N_s = n \times t$ (n from equation 6) the cleanliness level, X_1 becomes:

$$X_1 = 10 \qquad \text{Eq. 7}$$

where,

X_1 = Cleanliness level (per Mil-Std-1246A)

t = time in days

$n = (2.851 \times 10^3) \times N_c^{0.773}$

for,

$$N_c = 10^{(-2.173 + \log X_c)}$$

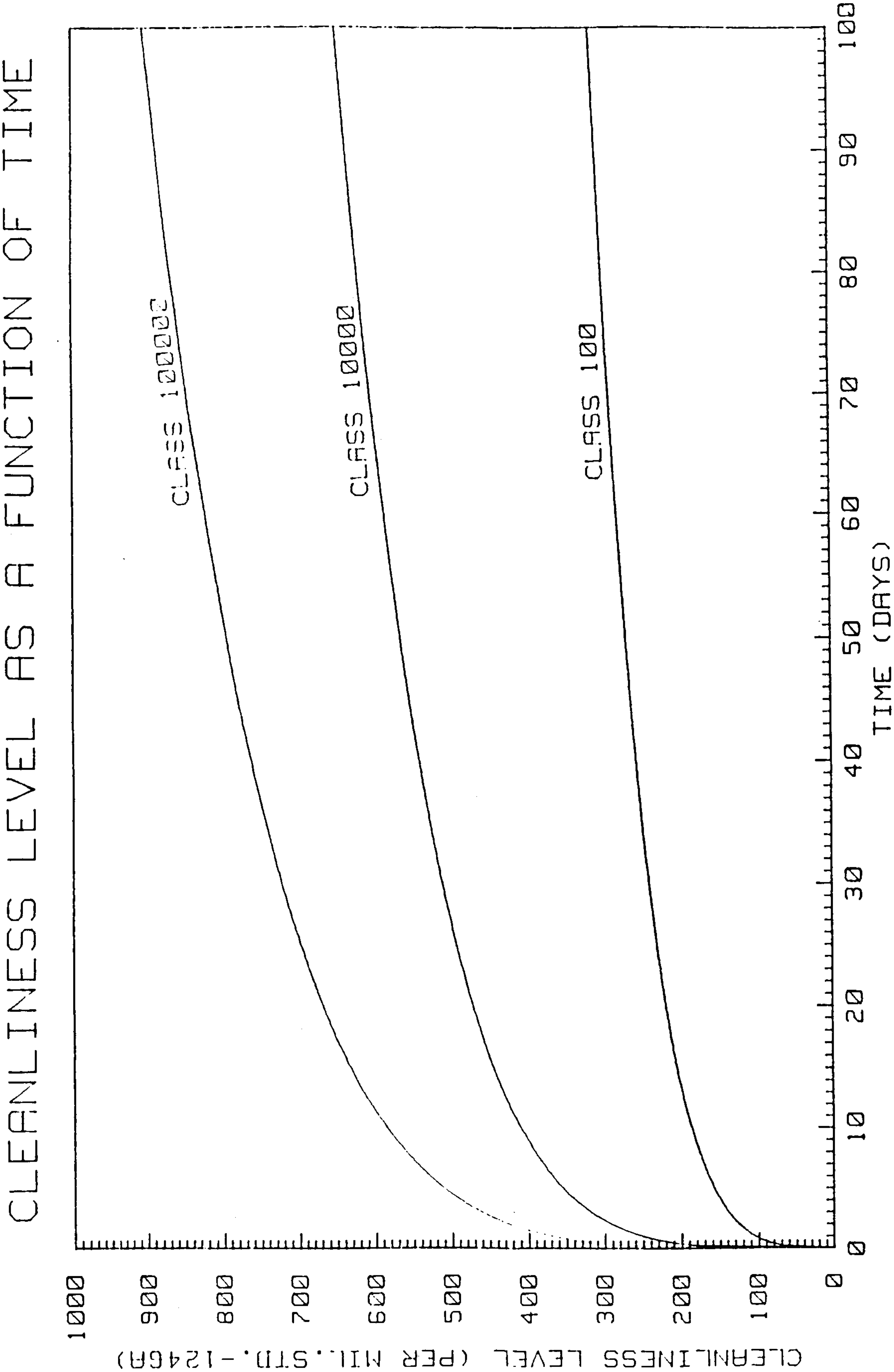
where,

X_c = Cleanroom class (per Fed. STd. 209B)

The result of the application of equation 7 is shown in Fig. 6.3 and 6.4. Fig. 6.3 shows the plot of surface cleanliness level versus exposure time for surfaces in environments corresponding to cleanroom classes 100, 10000, and 100000. Fig. 6.4 is the same data as Fig. 6.3 but with the exposure time (x- axis) plotted on a logarithmic scale.

6.3.1.6 <u>Use of Plots</u>

From the information given in Fig. 6.3 and 6.4 it is possible to determine the surface cleanliness level (per Mil.-Std.-1246A) degradation as a function of time in a given environmental cleanliness class (per Fed. Std. 209B). For example, if a surface was determined to be at a surface cleanliness level of 300, how long could the surface be exposed to a class 10000 environment before it degraded to a cleanliness level of 600. From Fig. 6.3 the surface cleanliness level 300 occurs at 1.5 days for a perfectly clean surface in a class 10000 environment. The surface



CLEANLINESS LEVEL AS A FUNCTION OF TIME
CLASS 100000
CLASS 10000
CLASS 100
CLEANLINESS LEVEL (PER MIL.STD.-1246A)
TIME (DAYS)
0
100
200
300
400
500
600
700
800
900
1000
0
10
20
30
40
50
60
70
80
90
100

FIGURE 6.3

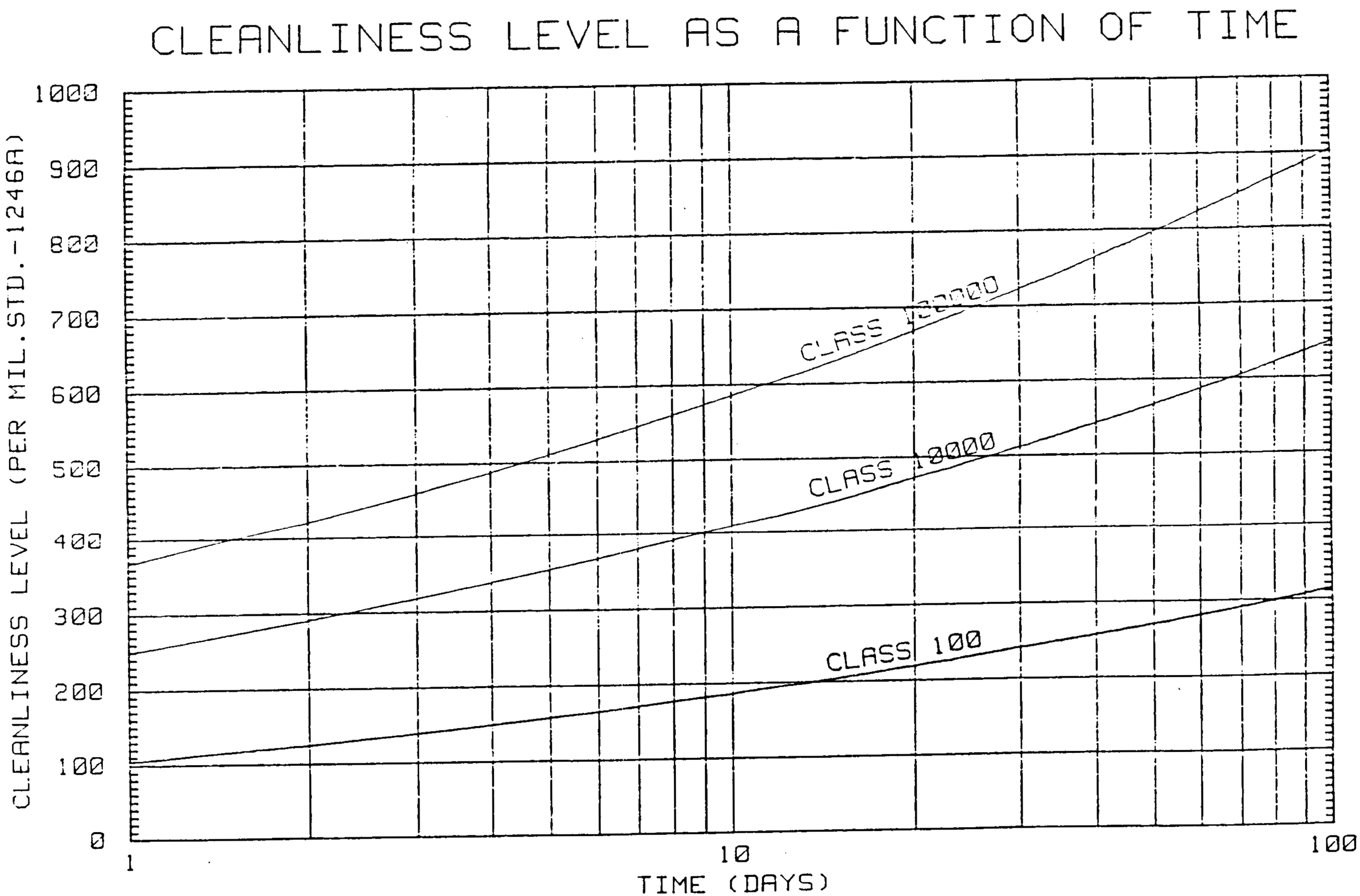

CLEANLINESS LEVEL AS A FUNCTION OF TIME
CLEANLINESS LEVEL (PER MIL.STD.-1246A)
1000
900
800
700
600
500
400
300
200
100
0
1
10
100
TIME (DAYS)
CLASS 100000
CLASS 10000
CLASS 100

FIGURE 6.4

cleanliness level 600 occurs at 70 days. Consequently, a surface at cleanliness level 300 would take 68.5 days to deteriorate to a surface cleanliness level 600 if kept in a class 10000 environment.

6.3.2 Subassembly Bakeout

By baking sub elements prior to final assembly, the risk of having an insurmountable or catastrophic problem during final assembly can be reduced or eliminated. This process should be ideally carried out until the optics are in place.

Materials such as painted structures, baffles and multilayer insulation should be baked out at the highest level possible. The temperature should be in excess of predicted flight temperatures.

An approach used by Dr. Ray Gause, MSFC on Space Telescope subcomponents is to hold their temperature at 10°C above final test temperature and a TQCM at -10°C which is positioned at distances comparable to critical surfaces when finally assembled. The criteria is that the TQCM level must reach 1.5×10^{-9}g cm^2/hr or 1 HZ/hr when averaged over 24 hours. Witness samples are covered and held at a high temperature near that of the subassembly until the TQCM reaches the deposition rate criteria. Then they are cooled and exposed for 24-36 hours. One criteria for the witness samples is a 3% change in the reflectance at say 1216 angstroms after the exposure. The actual criteria to be used is a function of the payload viewing spectrum and allowable degradation.

6.3.3 Acoustic Cleaning

Acoustic cleaning is used to remove particles from crevices and hard to reach places such as baffles. A cleaned nylon bristle brush and a black light can be used to verify surface cleanliness.

This process is important so that particles are not released into the optical system during the systems vibration test or during launch vibration.

The full up systems vibration test should be followed by a tape lift method or some other particulate optical test to verify cleanliness

6.3.4 Cleanliness Verification/Compliance Reporting

There are hardware installation operations prior to which must comply with specific cleanliness levels. For example, to determine the presence of particulate contamination 5 microns and larger a tape lift method which is currently being evaluated by an ASTM committee should be incorporated. Optical witness samples should be used to determine the exposure of optical surfaces to molecular contamination. The verification and sign off must be completed prior to installation. The following sections indicate the forms that may be used for the verification process and for procedures related to the production flow.

6.3.4.1 Hardware Acceptance

This form is an example of the documentation for the cleanliness verification process. It should be approved by flight assurance personnel. Figure 6.5 is a sample form to document the hardware acceptance criteria.

6.3.4.2 Integration Work Order

This form is intended as a tracking/approval mechanism for the various hardware installation activities. The approval to commence with the requested action will be required by flight assurance personnel. In addition, verification will be required at the completion of the action. Figure 6.6 is an example of the form to document the numerous tasks required for hardware integration.

CONTAMINATION LEVEL PROCEDURE/VERIFICATION DOCUMENTATION

HARDWARE ACCEPTANCE

DATE:______________

1. ITEM:

2. INTERFACES:

3. IMPOSED CLEANLINESS LEVEL REQUIREMENTS:

4. CLEANING TECHNIQUE UTILIZED TO REACH APPROVED LEVEL IF REQUIRED:

5. SURFACE CLEANLINESS LEVEL MEASURED:

Location	Measurement

6. MEASUREMENT TECHNIQUE EMPLOYED:

7. DATE OF MEASUREMENT:

8. STORAGE ENVIRONMENT SINCE MEASUREMENT:

9. HARDWARE ITEM REPRESENTATIVE SIGNATURE

______________________________ DATE______________________

10. SYSTEM ENGINEERING APPROVAL SIGNATURE

______________________________ DATE______________________

Figure 6.5

CONTAMINATION LEVEL PROCEDURE/VERIFICATION DOCUMENTATION

INTEGRATION WORK ORDER

DATE:________________

1. ACTION:

2. INTERFACES:

3. CONTAMINATION CONTROL TECHNIQUES TO BE IMPLEMENTED (if applicable):

4. CONTAMINATION CONTROL PLAN REFERENCE:

5. PERSONNEL PERFORMING ACTION:

6. APPROVAL TO COMMENCE ACTION, SYSTEM ENGINEERING

________________________________ DATE______________________

7. VERIFICATION ACTION COMPLETED SATISFACTORILY, SYSTEM ENGINEERING

________________________________ DATE______________________

Figure 6.6

6.3.4.3 Variance or Violation Report

This form can be used when a variance is necessary from a planned requirement or when a violation has occurred that may have an impact on the rest of the system elements or requires corrective action. For example, variances may occur when a particular required cleaning procedure does not apply to a specific hardware item or when storage requirements cannot be met. A violation may occur when a particle count of room air is very high, or an accidental spill occurs. The example form is shown in Figure 6.7.

6.4 FINAL ASSEMBLY

Final assembly should be completed in a clean room environment that is monitored for particulate and molecular deposition near critical areas.

The final assembly should be verified of its cleanliness level prior to system acoustic or thermal vacuum testing.

GSE equipment used in conjunction with flight hardware in a vacuum chamber should be baked out to the same criteria as flight hardware. This says the GSE equipment should be baked out at least 10°C above the GSE equipment temperature reached during testing with flight hardware.

Before final thermal vacuum testing the vacuum chamber and GSE equipment should be certified as to their cleanliness level. For the thermal vacuum chamber this may require a pump down and heating cycle with witness samples and a TQCM for verification prior to flight hardware testing.

6.5 SYSTEMS TESTING CONTAMINATION MONITORING

Monitoring of particulates and the non-volatile residues is required during the different phases of configured system testing. The frequency of measurements should be such that an assessment of surface cleanliness levels can be made. Periods of high, anomalous or unacceptable levels should be reported and corrective actions taken: Figure 6.7 is an example of a form which could be used for violations or variance requests.

Periodic inspections should be made to allow required cleaning or corrective actions to be implemented.

The types of monitoring for the different environments include,but are not limited to:

6.5.1 Thermal Vacuum Chamber

Particulate and NVR monitoring is required during certification and testing. Additionally, TQCM's are to be used under vacuum test conditions. Real time monitors, witness plates, wipe procedures, cryogenic cold fingers may be utilized as required.

Fig. 6.8 is a sample form to be used as a summary for readings and time notation for thermal vacuum chamber contamination monitoring summary.

6.5.2 Acoustic Testing

During acoustic testing the configured system and associated hardware may be double bagged. In this way the external bag can be removed if it is heavily contaminated, leaving a cleaner inner cover for removal from the chamber. To determine the potential of particulate transfer to the configured system during cover removal or penetration, the particulate atmosphere should be monitored just before the test commences and immediately after. In addition, witness plates inside the cover on or near

CONTAMINATION LEVEL PROCEDURE/VERIFICATION DOCUMENTATION

VARIANCE OR VIOLATION REPORT

DATE:____________________

1. VARIANCE REQUEST OR VIOLATION REPORT:

2. ITEMS/ACTION INVOLVED:

3. REPORTING PERSONNEL:____________________ DATE____________________

4. VARIANCE APPROVAL: If applicable

   ____ DATE____________________

5. CONTAMINATION IMPACT:

6. CORRECTIVE ACTIONS REQUIRED:

Figure 6.7

THERMAL VACUUM CHAMBER CONTAMINATION MONITORING SUMMARY

REPORT DATE: ____________________ SUBMITTED BY: ____________________

1. TEST TITLE/DESCRIPTION:

2. TEST ARTICLE INSTALLATION:	TIME/DATE	/	/	/
Air Class Measurement				
3. PUMPDOWN PERIOD:	TIME/DATE	/	/	/
Air Class Measurement				
4. WARMUP PERIOD:	TIME/DATE	/	/	/
Air Class Measurement				
5. TEST PERIOD:	TIME/DATE	/	/	/
Air Class Measurement				
TQCM READING				
Test Article	______			
Temps	______			
	______			
Chamber Wall Temp.				
Cold Finger on/off				
6. COOL DOWN PERIOD:	TIME/DATE	/	/	/
Air Class Measurement				
7. BACK FILL PERIOD:	TIME/DATE	/	/	/
Air Class Measurement				

8. CRYOGENIC COLD FINGER MEASUREMENT AND EXPOSURE TIME: __________, __________

9. WITNESS PLATES NVR AND EXPOSURE TIME: ______, ______/ ______, __________

10. WITNESS PLATES SURFACE CLASS AND EXPOSURE TIME: __________, __________

__________, ________ / __________, __________ / __________, __________

11. TEST ARTICLE SURFACE CLASS AFTER CHAMBER OPENED (if required): LOCATION ________ CLASS ________

________ ________

12. TEST ARTICLE NVR MEASUREMENT: LOCATION ________ CLASS ________

________ ________

________ ________

13. ACTIONS REQUIRED/COMMENTS:

Figure 6.8

2. Continued	/	/	/	/	/	/
3. Continued	/	/	/	/	/	/
4. Continued	/	/	/	/	/	/
5. Continued	/	/	/	/	/	/
6. Continued	/	/	/	/	/	/
7. Continued	/	/	/	/	/	/

Figure 6.8 (continued)

the configured system should be utilized to determine if particulates did migrate during the test. Fig. 6.9 is a sample form to record the contamination monitor results in a summary fashion for the acoustic test.

6.6 STORAGE/TRANSPORTATION ENVIRONMENT MONITORING

The monitoring/reporting of the environment and surfaces for hardware is required to document the cleanliness levels of the configured system and associated hardware at various times during the location.

Fig. 6.10 is a sample report form for the air class levels measured by particle count systems.

Fig. 6.11 is a sample report form for tape lift measurements to determine surface cleanliness levels.

Fig. 6.12 is a sample report form for non-volatile residue (NVR) measurements of surface cleanliness.

6.7 GENERAL PRACTICES/PROCEDURES

This section contains general guidelines to minimize contamination potential of flight hardware components. It is not intended to be all inclusive but rather to create an awareness of the range of precautions one must consider.

- o Personnel should be briefed or trained on all aspects of contamination control and procedures.
- o No smoking, eating or drinking around flight hardware
- o Maintain protective covers in critical areas at all times, control access and cleanliness levels during penetration of these covers
- o All bolt holes/penetrations, that are not used, must be sealed with an approved material to negate the possiblity of particles emitting from these cavities.

ACOUSTIC CHAMBER CONTAMINATION MONITORING SUMMARY

1. REPORT DATE: ____________ SUBMITTED BY: ____________________

2. TEST TITLE/DESCRIPTION:

3. TEST ARTICLE INSTALLATION PERIOD:	TIME/DATE	/	/
Air class measurements			
4. CHAMBER CLOSED PERIOD:	TIME/DATE	/	/
Air class measurements			
5. TEST COMPLETED PERIOD:	TIME/DATE	/	/
Air class measurements			

6. WITNESS PLATE(S) SURFACE CLASS:

Location	Surface class
________	______________
________	______________
________	______________

7. TEST ARTICLE SURFACE CLASS AFTER TEST: (if required)

Location	Surface Class
________	______________
________	______________
________	______________

8. ACTIONS REQUIRED:

FIGURE 6.9

AIR CLEANLINESS LEVEL REPORT FORM

REPORTED BY: ____________ EXT: ________ DATE: ________

SUBJECT:

LOCATION:

SAMPLE DATE/TIME: ____________, ____________

TEMPERATURE: ____________ °F , RELATIVE HUMIDITY ______%

DEW POINT: ____________

ACTIVITY: ____________

AIR CLASS: ____________

REMARKS: ____________

____

CORRECTIVE ACTIONS: ____________

SIGNATURE: ____________ DATE ________

AIR CLEANLINESS LEVEL REPORT FORM

REPORTED BY: ____________ EXT: ________ DATE: ________

SUBJECT:

LOCATION:

SAMPLE DATE/TIME: ____________, ____________

TEMPERATURE: ____________ °F , RELATIVE HUMIDITY ______%

DEW POINT: ____________

ACTIVITY: ____________

AIR CLASS: ____________

REMARKS: ____________

____

CORRECTIVE ACTIONS: ____________

SIGNATURE: ____________ DATE: ________

FIGURE 6.10

TAPE SAMPLE REPORT FORM

DATE: ____________________ TEST PERFORMED BY: ______________________________

PARTICLE SIZE MICRONS	# OF PARTICLES	DESCRIPTION OF PARTICLES	LOCATION OF TAPE SAMPLE
5 - 15			
16 - 35			
36 - 75			
76 - 100			
151 - 200			
201 - 300			
301 - 400			
401 - 750			
751 - 1250			
1251 - 2000			

CLEANLINESS LEVEL = ______________________________

CORRECTIVE ACTIONS: ______________________________

TAPE SAMPLE REPORT FORM

DATE: ____________________ TEST PERFORMED BY: ______________________________

PARTICLE SIZE MICRONS	# OF PARTICLES	DESCRIPTION OF PARTICLES	LOCATION OF TAPE SAMPLE
5 - 15			
16 - 35			
36 - 75			
76 - 150			
151 - 200			
201 - 300			
301 - 400			
401 - 750			
751 - 1250			
1251 - 2000			

CLEANLINESS LEVEL = ______________________________

CORRECTIVE ACTIONS: ______________________________

FIGURE 6.11

NON VOLATILE RESIDUE REPORT FORM

DATE: ________________ TASK PERFORMED BY: ________________

HARDWARE ITEM: ________________________________

LOCATION(S): ________________________________

____

SAMPLE DATE/TIME: ________________, ________________

TEST METHOD UTILIZED: ________________________________

____

NVR: ________________ AREA SAMPLED

________________ ________________

________________ ________________

REMARKS: ________________________________

____

CORRECTIVE ACTIONS: ________________________________

NON VOLATILE RESIDUE REPORT FORM

DATE: ________________ TEST PERFORMED BY: ________________

HARDWARE ITEM: ________________________________

LOCATIONS(S): ________________________________

SAMPLE DATE/TIME: ________________, ________________

TEST METHOD UTILIZED: ________________________________

____

NVR: ________________ AREA SAMPLED

________________ ________________

________________ ________________

REMARKS: ________________________________

____

CORRECTIVE ACTIONS: ________________________________

FIGURE 6.12

- During mounting of hardware
  - no cutting oils sould be used
  - use of tools that produce particles (i.e. drills, saws) should be used in conjunction with a vacuum
  - drilled holes should be deburred and vacuumed
  - wear gloves when handling thermal baked out components
- Maintain all handling fixtures, GSE and tools in a visibly clean condition
- Use only flight qualified materials, select paints, plastics, adhesives, lubricants, wire insulation, cable sleeving and other non-metallic materials to minimize contamination
- Never assume any item recieved from elsewhere is clean. Ask for verification from source or verify before use
- Monitor environments constantly
- Question any material, procedure or hardware you are not sure of
- Establish a documented verification system for all assembly procedures and testing.

7.0 CONCLUSIONS/RECOMMENDATIONS

After updating the contamination requirements document and presenting the results of the trade studies to OSSA CODE E, it became apparent more detail of degradation of optical systems is required. This is especially true for the effect of number column density that resides in the field-of view of the instruments. For each molecular and atomic specie the absorption, scattering and emissions at all wavelengths must be determined. In this way a predicted number column density can be stated in terms of spectral signal loss or background brightness increase. These predicted signal changes, relative to an undisturbed background, can be compared to each experiment allowable signal degradation as determined by the principal investigator and his staff.

This is not an easy task, especially for emissions, because of the number of excitation mechanisms and their variability throughout a complete orbit and from orbit to orbit.

Preliminary comparisons of the transverse boom configuration to the dual keel showed that the transverse boom is more of a contamination problem. This results from the positioning of payloads near the major contamination sources of leakage, RCS and the relative position of large solar arrays and radiators. Clearly the dual keel is the preferred configuration of the two options.

The venting studies showed that a region 1 and region 2 concept for allowable vent contributions is not a good concept because of the uncertainty in vent plume distributions and configuration changes of the space station requires redefinition of the different regions.

It appears that some low level of continuous venting may be allowable and not exceed the column density requirements. However, until the actual spectral degradation of the contaminants is established this rate is not clear. Another issue that may restrict venting at any flow rate, is the impact of the gases on the near plasma environment of the Space Station.

Another important conclusion is that the majority of the payload personnel contacted during this study are not well aware of contamination and its potential impact. There are notable exceptions, but in general, allowable limits of deposition and number column densities were unknown. Also, the effects of atomic oxygen erosion and orbital debris appeared to be a surprise to most contacts that were made. For these reasons the final report was structured to contain, as much as possible, sections that should aid in developing an awareness of contamination and its potential impact.

During the space station development it is recommended that a space station Users Contamination Handbook or Guide be developed so that all personnel will use proper approaches and criteria. Sections 2 and 6 of this report are preliminary beginnings of such a handbook. After detailed analysis of space station environments, the data for such a handbook would increase substantially.

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15. SUPPLEMENTARY NOTES

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16. ABSTRACT

Two physical models of component plus supporting substructure are considered. Each model consists of a rigid body attached to a moving base by means of linear springs and viscous dampers. The second model differs from the first in that its dampers are elastically supported. The first model receives the more extensive treatment. Base motion, assumed a random translational motion parallel to a fixed axis, is prescribed only to the extent that the power spectral density (PSD) of its acceleration is given; and, as given, its plot on log-log graph paper is a series of straight line segments, each segment having an extremity in common with the adjacent segment. Closed expressions are given for the mean squares of base acceleration, base velocity, and base displacement. The component is restricted to planar motion and allowed two degrees of freedom, one translational and one rotational. Integral expressions are given for the mean squares of component response variables, the transfer functions essential to mean square computation being available via the equations of motion. Closed expressions are given for mean squares of certain of the response variables for the case wherein the base acceleration PSD is constant. A very brief paragraph is given to stability of motion.

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